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A

MANUAL OF PALÆONTOLOGY

A

MANUAL OF PALÆONTOLOGY

FOR THE USE OF STUDENTS

WITH A GENERAL INTRODUCTION ON THE
PRINCIPLES OF PALÆONTOLOGY

BY

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PART II.

PALÆOZOOLOGY

(CONTINUED)

ERRATUM.

Vol. II., pages 134 and 138. The reader will kindly delete "Platysomidæ" from the list of *sub-orders* of Ganoids, and place these fishes next after the Palæoniscidæ as a *family* of Lepidosteidæ. The author regrets that, having had only a hurried glance over the proof-sheets of his friend's paper on the Platysomidæ, he has, through inadvertence, made the erroneous statement (p. 138, foot-note), that the elevation of the Platysomidæ to the rank of a distinct sub-division of Ganoids is in accordance with the views of Dr Traquair. On the contrary, Dr Traquair holds that the Platysomidæ constitute a *family*, very distinct from the Pycnodontidæ, but closely allied to the Palæoniscidæ, and that the position of both Palæoniscidæ and Platysomidæ is rather in the sub-order Acipenseroidei.

In their habits the Gasteropods show great differences, most of them being free and locomotive, though some are sedentary. The typical forms move about more or less actively by the successive contractions and expansions of a muscular organ developed upon the ventral surface of the body and known as the "foot." In many cases the posterior

PALÆONTOLOGY.

CHAPTER XXIV.

GASTEROPODA.

The Gasteropods are *Molluscs in which the body is furnished with a distinct head, and the mouth is provided with a masticatory apparatus or "lingual ribbon." Locomotion is effected by means of a broad, horizontally-flattened, ventral disc—the "foot"—or by a vertically-flattened, fin-like modification of the same. The body is never included in a bivalve shell; and may be naked. Usually, however, there is a "univalve" shell, or in some cases a "multivalve" shell.*

This class includes all those Molluscous animals which are commonly known as "Univalves," such as Land-snails, Sea-snails, Whelks, Limpets, &c. In the Chitons, however, the shell is composed of eight pieces ("multivalve"); and in the Slugs the shell is minute and completely concealed in the mantle; whilst in the Sea-slugs and Sea-lemons the animal is "naked," and is destitute of a shell.

In their habits the Gasteropods show great differences, most of them being free and locomotive, though some are sedentary. The typical forms move about more or less actively by the successive contractions and expansions of a muscular organ developed upon the ventral surface of the body and known as the "foot." In many cases the posterior

portion of the foot secretes a calcareous, horny, or fibrous plate, which is called the "operculum" (fig. 382, *o*), and which serves to close the aperture of the shell when the animal is retracted within it. Lastly, in one aberrant group of the Gasteropods (*Heteropoda*) the animal is fitted for swimming in the open ocean, by the conversion of the "foot" into a vertically-flattened fin.

The respiratory process in the Gasteropods differs considerably in different cases; and the class may be divided

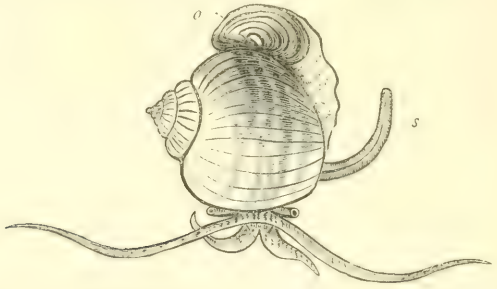


Fig. 382.—*Ampullaria canaliculata*, one of the Apple-shells. *o*, Operculum; *s*, Respiratory siphon.

into two principal sections, according as the animal is fitted for breathing air directly or through the medium of water. The air-breathing Gasteropods are known as the *Pulmonata* or *Pulmonifera*, and comprise forms which either live on land (Snails, Slugs, &c.), or which inhabit fresh water (Pond-snails, &c.) The water-breathing Gasteropods are mostly provided with distinct gills or "branchiæ," and they form the section of the *Branchifera*. They are mostly inhabitants of the sea; but some of them inhabit fresh water.

Shell of the Gasteropoda.—The shell of the *Gasteropoda* is composed either of a single piece (univalve), or of a number of plates succeeding one another from before backwards (multivalve). The univalve shell is to be regarded as essentially a cone, the apex of which is more or less oblique. In the simplest form of the shell the conical shape is retained without any alteration, as is seen in the common Limpet (*Patella*). In the great majority of cases, however, the cone is considerably elongated, so as to form a tube, which may retain this

shape (as in *Dentalium*), but is usually coiled up into a spiral. The "spiral univalve" (fig. 384) may, in fact, be looked upon as the typical form of the shell in the *Gasteropoda*. In some cases the coils of the shell—termed technically the "whorls"—are hardly in contact with one another (as in *Vermetus*). More commonly the whorls are in contact, and are so amalgamated that the inner side of each convolution is formed by the pre-existing whorl. In some cases the whorls of the shell are coiled round a central axis *in the same plane*, when the shell is said to be "discoidal" (as in the common fresh-water shell *Planorbis*). In most cases, however, the whorls are wound round an axis in an oblique manner, a true spiral being formed, and the shell becoming "turreted," "trochoid," "turbinated," &c. This last form (fig. 383) is the one which may be looked upon as most characteristic of the Gasteropods, the shell being composed of a

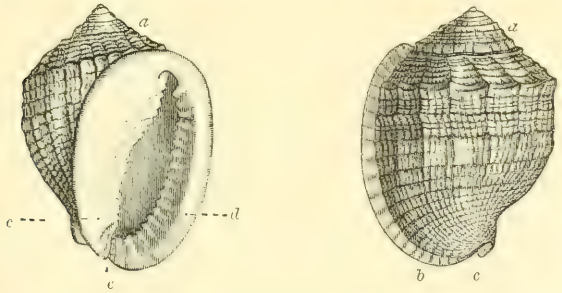


Fig. 383.—*Cassis cancellata*, a spiral Gasteropod. *a*, The "spire," placed at the posterior end of the shell; *b*, The "mouth," placed at the anterior end of the shell; *c*, Inner or columellar lip; *d*, Outer lip; *e*, Notch for the passage of a respiratory siphon.

number of whorls passing obliquely round a central axis or "columella," having the embryonic shell or "nucleus" at its apex, and having the mouth or "aperture" of the shell placed at the extremity of the last and largest of the whorls, termed the "body-whorl." The lines or grooves formed by the junction of the whorls are termed the "sutures," and the whorls above the body-whorl constitute the "spire" of the shell. The axis of the shell (columella) round which the whorls are coiled is usually solid, when the shell is said to be "imperforate;" but it is sometimes hollow, when the shell is said

to be "perforated," and the aperture of the axis near the mouth of the shell is called the "umbilicus." The margin of the "aperture" of the shell is termed the "peristome," and is composed of an outer and inner lip (fig. 383), of which the former is often expanded or fringed with spines. When these expansions or fringes are periodically formed, the place of the mouth of the shell at different stages of its growth is marked by ridges or rows of spines, which cross the whorls, and are called "varices." The animal withdraws into its shell by a retractor muscle, which passes into the foot, or is attached to the operculum; its scar or impression being placed, in the spiral Univalves, upon the columella.

Fig. 384. — *Scalaria Grœnlandica*, a Holostomatous Univalve. Post-Pliocene.

Fig. 385. — *Fusus tornatus*, a Siphonostomatous Univalve. Post-Pliocene.

In the multivalve Gasteropods the shell is composed of eight transverse imbricated plates, which succeed one another from before backwards, and are embedded in the leathery or fibrous border of the mantle, which may be plain, or may be beset with bristles, spines, or scales.

In the marine Univalves two important variations exist in the form of the mouth of the shell. In one group (fig. 384) the mouth of the shell is unbroken or "entire," not having

any notch or indentation of its margin. The shells in which the mouth has this form are termed "holostomatous;" and for the most part they belong to Gasteropods which are phytophagous, or live upon vegetable food. The possession, however, of a holostomatous shell in reality simply proves that the animal had no respiratory "siphons," or tubes formed by the folding of the mantle. In a second group the aperture of the shell (fig. 385) is notched in front; and the shell is said to be "siphonostomatous." There may be a posterior notch as well as the anterior one, and one or both of these notches may be produced into longer or shorter canals. The Siphonostomatous Univalves are mainly carnivorous in their habits; but the notched mouth does not necessarily indicate the nature of the food. The possession of a siphonostomatous shell, on the contrary, merely indicates that the animal possessed tubular inflections of the mantle, or "respiratory siphons," by which the water is conveyed to and from the gills.

Divisions of the Gasteropoda.—The following table shows the chief divisions of the *Gasteropoda*:—

Table of the Gasteropoda.

Section A. Branchifera.—Respiration aquatic, by the walls of the mantle-cavity or by gills.

Order I. Prosobranchiata.—The branchiæ situated (*proson*) in advance of the heart.

Division a. Siphonostomata.—Margin of the shell-aperture notched or produced into a canal. This division comprises the families of the *Strombidæ* (Wing-shells), *Muricidæ*, *Buccinidæ* (Whelks), *Conidæ* (Cones), *Volutidæ* (Volutes), and *Cypræidæ* (Cowries).

Division b. Holostomata.—Margin of the shell-aperture "entire," rarely notched or produced into a canal. This division includes the families of the *Naticidæ*, *Pyramidellidæ*, *Cerithiadæ*, *Melaniadæ*, *Turritellidæ*, *Littorinidæ* (Periwinkles), *Paludinidæ* (River-snails), *Neritidæ*, *Turbinidæ* (Top-shells), *Haliotidæ*, *Fissurellidæ* (Keyhole-limpets), *Calyptræidæ* (Bonnet-limpets), *Patellidæ* (Limpets), *Dentalidæ* (Tooth-shells), and *Chitonidæ*.

Order II. Opisthobranchiata.—Branchiæ placed towards the rear (*opisthen*) of the body.

Division a. Tectibranchiata.—Branchiæ covered by the shell or mantle. A shell in most. Sexes united. The division includes

the families of the *Tornatellidæ*, *Bullidæ* (Bubble-shells), *Aplysiadæ* (Sea-hares), *Pleurobranchiadæ*, and *Phyllidiadæ*.

Division b. Nudibranchiata.—Animal destitute of a shell in the adult condition. Branchiæ external, on the back or sides of the body. This division includes the various naked Gasteropods commonly known as Sea-lemons and Sea-slugs.

Order III. Nucleobranchiata, or Heteropoda.—Shell present or absent. Animal free-swimming and oceanic, with a fin-like tail or flattened ventral fin. This order includes the two families of the *Firolidæ* and *Atlantidæ*.

Section B. Pulmonifera.—Respiration aerial, by means of a pulmonary chamber.

Order IV. Inoperculata.—Shell not provided with an operculum. This order comprises the families of the *Helicidæ* (Land-snails), *Limacidæ* (Slugs), *Oncidiadæ*, *Limnæidæ* (Pond-snails), and *Auriculidæ*.

Order V. Operculata.—Shell provided with an operculum. In this order are the families *Cyclostomidæ* and *Aciculidæ*.

Distribution of the Gasteropoda in time.—As regards the general distribution of the Gasteropods in past time, all the families of the *Prosobranchiata* are known by fossil representatives. Of the *Opisthobranchiata* the Tectibranchiate section is tolerably well represented in past time; but the section of the *Nudibranchiata*, from the total absence of the shell, is not known at all in the fossil condition. Both families of the *Heteropoda* are represented by fossil forms. The Pulmonate Gasteropods, from the fact that they either live on land or inhabit fresh water, are necessarily not so fully represented in past time as are the Branchiate Gasteropods. Still, nearly all the families of the air-breathing Univalves have fossil representatives.

Taken as a whole, the *Gasteropoda* are represented in past time from the Upper Cambrian rocks upwards. Of the *Branchifera*, the *Holostomata* are more abundant in the Palæozoic period; and the *Siphonostomata* predominate more in the Secondary and Tertiary periods, attaining their maximum at the present day. The place of the carnivorous *Siphonostomata* in the Palæozoic seas appears to have been filled by the Tetrabranchiate Cephalopods. The Branchiate Gasteropods of fresh water are chiefly represented as fossils by the genera *Paludina*, *Valvata*, and *Ampullaria*.

The *Heteropoda* are likewise of very ancient origin, having commenced their existence in the Upper Cambrian deposits. The genera *Bellerophon*, *Cyrtolites*, and *Maclurea* are exclusively Palæozoic; *Bellerophina* is found in the Gault (Secondary), and *Carinaria* has been detected in the Tertiaries.

The Pulmonate *Gasteropoda*, as was to be anticipated, are not found abundantly as fossils, occurring chiefly in lacustrine and estuarine deposits, in which the genera *Limnæa*, *Physa*, *Ancylus*, &c., are amongst those most commonly represented. These, however, are entirely Mesozoic and Kainozoic. In the Palæozoic period the sole known representatives of the *Pulmonifera* are the *Pupa vetusta*, *Pupa vermilionensis*, *Dawsonella Meeki*, and *Zonites priscus* of the Carboniferous rocks.

In the following[1] are given the characters of those families of the *Gasteropoda* which occur in the fossil state, with the leading genera of each family and their range in time.

Section A. Branchifera.—Respiration aquatic, generally by gills.

Order I. Prosobranchiata.—*Gills situated in advance of the heart.*

Division a. Siphonostomata.—Mouth of the shell notched, or produced into a canal.

Fam. 1. Strombidæ.—Shell with an expanded lip, deeply notched near the canal. Operculum claw-shaped. Foot narrow, adapted for leaping. All the existing genera of the *Strombidæ* are represented in the fossil state, but the family does not seem to have come into existence before the Jurassic period, and it attained its maximum in the Tertiary period.

The genus *Strombus* has a shell with a short spire, a long aperture, and an expanded outer lip, there being a posterior as well as an anterior notch. The Strombs are represented in the Cretaceous and Tertiary rocks, but they attain their maximum in existing seas.

The Scorpion-shells form the genus *Pteroceras* (fig. 386), in

[1] In the characters of the families of the *Gasteropoda*, as in those of the *Lamellibranchiata*, Woodward's 'Manual of the Mollusca' has been mainly followed.

which the shell of the adult has its outer lip furnished with long claws, one of which forms a posterior canal close to the

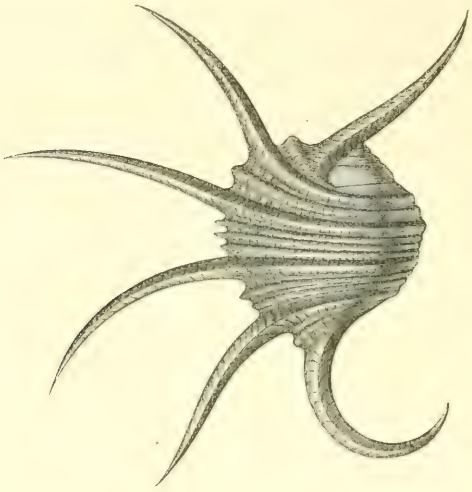


Fig. 386.—*Pteroceras oceani*. Neocomian.

spire. Many fossil species are known, commencing in the Lias.

In the genus *Rostellaria* (fig. 387), the spire is long, and has the posterior canal running up it. Many fossil species are known, commencing in the Cretaceous rocks. The outer lip is always expanded, and in some forms is enormously so. One of the most familiar species is the great *R. ampla* (fig. 387) of the London Clay (Eocene). Lastly, the genus *Seraphs* comprises smooth shells, with a short or obsolete spire, a thin outer lip, and a long narrow mouth. The fossil species date from the Eocene Tertiary.

Fam. 2. Muricidæ.—Shell with a straight anterior canal, the aperture entire posteriorly. Foot broad. The *Muricida* are essentially characteristic of the Tertiary and Recent periods. They commence, however, in the Jurassic rocks, in some doubtful examples, and they are certainly represented in the Cretaceous rocks by not a few forms.

In the genus *Murex* the canal is often very long, and may be partially closed; the shell is ornamented with lon-

gitudinal ridges or rows of spines (*varices*), and the aperture is rounded.

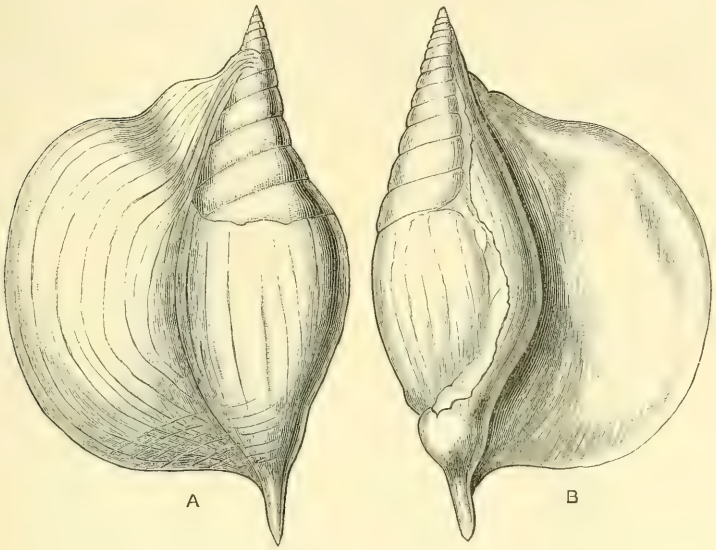


Fig. 387.—*Rostellaria ampla*, reduced one-third. Eocene Tertiary.

In the nearly-related *Typhis* (fig. 388) there are tubular spines between the varices, and the last of these lodges the posterior siphon. Both *Murex* and *Typhis* commence in the Eocene Tertiary, and have attained their maximum in existing seas. *Trophon*, like the preceding, ranges from the Cretaceous to the present day; and *Fulgur* (fig. 391, D) is a Tertiary and Recent form.

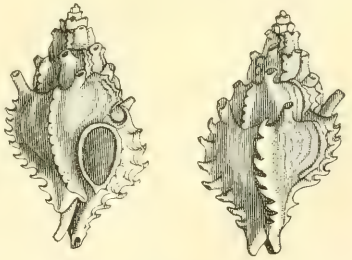


Fig. 388.—*Typhis tubifer*. Eocene Tertiary.

Pisania commences to be represented in the Eocene, as do the genera *Ranella*, *Triton*, and *Cancellaria*. *Fasciolaria* and *Pyrula* (fig. 391, E) commence their existence in the Cretaceous rocks; and *Turbinella* and *Trichotropis* do not make their appearance till the Miocene. Lastly, the great genus

Fusus, distinguished by the spindle-shaped, many-whorled shell, and long straight canal (fig. 389), appears to have its commencement in the Oolites. Species of *Fusus* become very numerous towards the close of the Cretaceous period, and they are very plentiful in the Tertiaries. One of the common fos-

Fig. 389.—*Fusus Neocomiensis.* Lower Greensand.

Fig. 390.—*Buccinum undatum* (*var.*) Post-Pliocene and Recent.

sils of the Red Crag (Newer Pliocene) is the reversed shell, *Fusus contrarius* (fig. 391, F), which is now known to exist in the living state as well.

The most ancient representative of the *Muricidæ*, if rightly referred here, is probably the genus *Fusispira* (fig. 391, A), of the Lower and Upper Silurian. In this genus the shell is fusiform, with an elevated spire, the mouth being elliptical and produced below, and the columella twisted, but without folds.

Fam. 3. Buccinidæ.—Shell notched anteriorly, or with the canal reflected, producing a kind of varix on the front of the shell. With the exception of the extinct genus *Purpurina* of the Lower Oolites, and some species of *Buccinum* in the Cretaceous rocks, the family of the *Buccinidæ* is exclusively confined to the Tertiary and Recent periods. The two great families, therefore, of the *Muricidæ* and *Buccinidæ* are essentially characteristic of the later periods of the

earth's history. The most important fossil genera of the *Buccinidæ* are *Buccinum, Terebra, Nassa, Purpura, Cassis,* and *Oliva.*

The Whelks form the genus *Buccinum* (fig. 390), distinguished by the ventricose body-whorl, large aperture, and short reflected canal. Some few species of *Buccinum* are found in the Cretaceous rocks; but the genus is essentially Tertiary and Recent.

Terebra comprises the Auger-shells, distinguished from the Whelks by their long, pointed shells, consisting of many

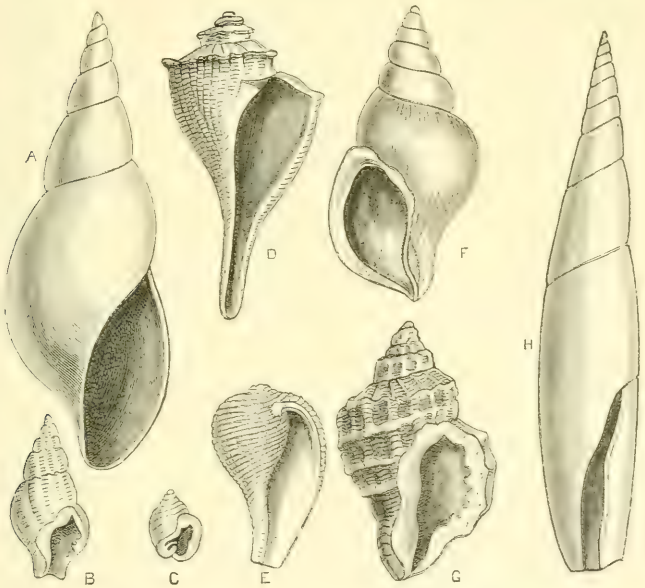


Fig. 391.—A, *Fusispira terebriformis*—Lower Silurian (after Hall); B, *Nassa pusillina*—Pliocene (after Searles Wood); C, *Ringicula ventricosa*—Pliocene (after Searles Wood); D, *Fulgur canaliculatus*—Miocene; E, *Pyrula reticulata*—Pliocene; F, *Fusus contrarius*—Pliocene; G, *Purpura tetragona*—Pliocene (after Searles Wood); H, *Subulites terebriformis*—Upper Silurian (after Hall).

whorls, and having a small mouth. They commence in the Eocene Tertiary. The Dog-whelks (*Nassa*) also commence in the Eocene, and are distinguished from the Whelks chiefly by having the columellar lip expanded and callous, with a tooth near the anterior canal (fig. 391, B). The shells of the genus *Purpura* (fig. 391, G) have a short spire and wide

aperture, with an expanded and flattened inner lip. They commence in the Miocene Tertiary. *Ringicula* (fig. 391, c) has a ventricose shell, with a small spire, the columella callous and deeply plaited, and the outer lip thickened and reflected. The genus commences in the Miocene Tertiary, and is represented by living species. We may also, perhaps, place in this family, possibly in the neighbourhood of *Terebra*, the Silurian genus *Subulites* (391, H), which in this case is the most ancient representative of the family *Buccinidæ*. The shell in this genus is very long and slender, with a long spire, and an extended body-whorl. The mouth is narrow, with a sharp, not callous lip; the columella is truncated below, not plaited or toothed; and there is a deep basal notch. The Helmet-shells (*Cassis*) begin in the Eocene, and are distinguished by their short spire, large body-whorl, long aperture, recurved canal, and expanded inner lip. Lastly, the Olives (*Oliva*, fig. 392, A) and Rice-shells (*Olivella*) are characterised by their cylindrical polished shell, with a short spire, a long narrow aperture, notched in front, and an obliquely-striated columella. The living Olives are tropical and subtropical in their distribution, and the fossil species, except for two or three Cretaceous species of *Olivella*, commence in the Eocene Tertiary. *Ancillaria* (fig. 392, B), dating from the Eocene, is nearly related to *Oliva*, but the spire is produced, and wholly covered with enamel.

Fam. 4. Conidæ.—Shell inversely conical, with a long narrow aperture, the outer lip notched at or near the suture. The *Conidæ* commence in the Cretaceous rocks, abound in the Tertiaries, and attain their maximum at the present day.

The true Cones form the genus *Conus* (fig. 392, C), and are distinguished by their short spire and regularly conical shell, of which the outer lip is notched near the suture. The Cones are represented in the Chalk, but are mainly Tertiary and Recent. *Gosavia* comprises Cones with a plaited columellar lip, and is essentially a Cretaceous type. The genus *Pleurotoma* (fig. 392, D) is distinguished by a spindle-shaped shell, with a long spire, the outer lip having a deep slit near the suture. The genus commences in the Chalk, and has an enormous development in the Tertiaries,

from which nearly three hundred species are known. The maximum, however, is attained in existing seas, in which

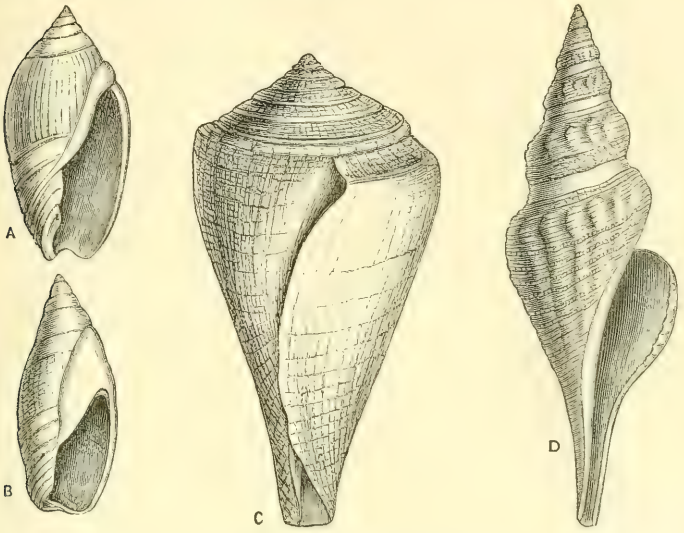


Fig. 392.—A, *Oliva Branderi*—Eocene; B, *Ancillaria glandina*—Eocene; C, *Conus deperditus*—Eocene; D, *Pleurotoma rostrata*—Eocene.

there are very numerous species. *Borsonia*, dating from the Eocene, is near the preceding, but has an obliquely-folded columella.

Fam. 5. Volutidæ. — Shell turreted or convolute, the aperture notched in front; the columella obliquely plaited. No operculum. Foot very large; mantle often reflected over the shell. The living members of the *Volutidæ* are chiefly inhabitants of warm seas, and are often remarkable for their brilliant colours. The family does not appear to have existed till towards the later portion of the Cretaceous period; but it is abundantly represented in the Tertiaries, and attains its maximum in existing seas. The most important genera are *Voluta* and *Mitra*.

The true Volutes form the genus *Voluta* (fig. 393), characterised by the short spire, large, deeply-notched aperture, and columella with several plaits. Species of *Voluta* occur in the Cretaceous period, but the genus is mainly Tertiary and

Recent. There are several sub-genera of *Voluta*, the most important being the Eocene *Volutilithes*, with its many-whorled spire. In the genus *Mitra* the shell is spindle-shaped, with a long spire and small mouth. The *Mitræ* commence in the Cretaceous period, but the fossil species are mainly distributed through the Tertiary formations. *Columbellina* and *Lyria* are Cretaceous; and the living genera *Volvaria* and *Marginella* begin in the Eocene.

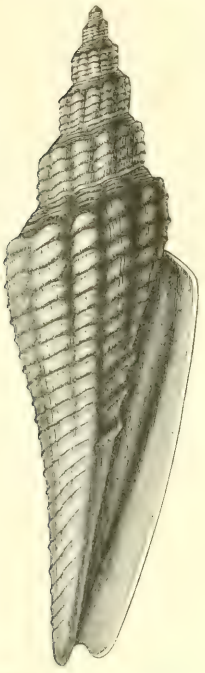


Fig. 393.—*Voluta elongata.* Chalk.

Fam. 6. Cypræidæ. — Shell convolute, enamelled; spire concealed; aperture narrow, channelled at each end. Outer lip thin in the young shell, but thickened and inflected in the adult. Foot broad; mantle forming lobes which meet over the back of the shell. The only important genus of this family is that of *Cypræa* (fig. 394), comprising the numerous and well-known living shells which are commonly called Cowries. The *Cyprææ* are mainly, but not exclusively, inhabitants of warm seas, and they attain their highest development between the tropics. The fossil species date from the Cretaceous period, and abound in the Tertiaries.

The shell of the Cowries in the young state is furnished with a prominent spire, and has a thin outer lip. In the adult state (fig. 394) the spire is completely concealed within the shell, the entire surface is generally covered with shining enamel, the inner lip is crenulated, and the outer lip is thickened, inflected, and crenulated. The small Cowries of which *Cypræa Europæa* is the type, are not known as occurring in the fossil condition. *Ovulum*, dating from the Eocene, resembles *Cypræa*, but the inner lip is smooth.

Division b. Holostomata. — Margin of the shell-aperture "entire," rarely notched or produced into a canal.

Fam. 7. Naticidæ.—Shell globular, of few whorls, with a small spire; outer lip acute; inner lip (pillar) often callous. Foot very large; mantle-lobes hiding more or less of the shell. This family is stated to commence in the Upper Silurian rocks; but there is considerable uncertainty as to the true affinities of the Palæozoic fossils which are referred here. The most important fossil genus is *Natica* itself.

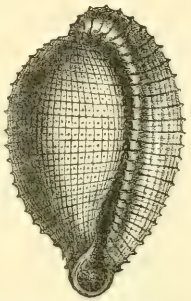


Fig. 394.—*Cyprœa elegans.* Eocene Tertiary.

The shell in *Natica* (fig. 395) is thick, smooth, and polished, often with coloured markings. The inner lip is callous, and the shell is umbilicated. Fossil *Naticæ* have been described from the Upper Silurian, Devonian, Carboniferous, and Permian rocks; and they are very abundant in all the Secondary and Tertiary formations. There is great doubt about the true affinities of the more ancient shells referred here; and the typical *Naticæ*, with a wide umbilicus and a twisted columella, are represented by very few forms even in the Cretaceous period. *Naticopsis* (fig. 397, B) of the Carboniferous; *Naticella* of the Trias; the Jurassic *Euspira*, with its elevated spire and angulated whorls; and the Tertiary *Globulus*, are close allies of *Natica* proper. *Narica* (fig. 397, C), with its spirally-striated shell, and *Amaura*, range from the Cretaceous to the present day. *Deshayesia*, of the Eocene, is a link between the *Naticidæ* and *Neritidæ;* and *Sigaretus* (fig. 397, A), ranging from the Eocene to the Recent period, is easily recognised by its wide aperture and minute spire.

Fig. 395.—*Natica clausa.* Post-Pliocene.

Fam. 8. Pyramidellidæ.—Shell turreted, with a small aperture; sometimes with one or more prominent plaits on the columella. Operculum horny and imbricated. The *Pyramidellidæ* commence in the Lower Silurian rocks, and appear to be on the decline at the present day. The chief

fossil forms belong to the genera *Pyramidella, Chemnitzia, Eulima, Loxonema,* and *Macrocheilus.*

In *Pyramidella* (fig. 397, D) the shell is slender and turreted, and the columellar lip is plaited. The genus is doubtfully represented in the Cretaceous, but there are various Tertiary and many living species. *Odostomia,* with a few Cretaceous representatives, but occurring more abundantly in the Tertiary, includes minute turreted shells with a single tooth-like columellar fold.

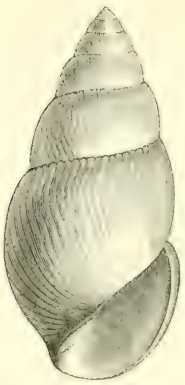


Fig. 396.—*Macrocheilus subcostatus.* Devonian.

Chemnitzia (fig. 397, G) includes a number of slender, turreted, many-whorled shells, with plaited whorls, and a simple aperture. The genus appears to commence in the Permian rocks, and whilst more than one hundred and fifty fossil species are known, the number of the living forms is very small. Many of the shells, however, included under this head, are of very doubtful affinities.

Eulima (fig. 397, F) includes small, polished, elongated shells, with level whorls and a reflected inner lip. *Eulimæ* are of doubtful occurrence in the Carboniferous rocks, are sparingly represented in the Secondary rocks, and are tolerably abundant in the Tertiaries.

Loxonema (fig. 397, E) extends from the Silurian to the Trias, but is most abundant in the Carboniferous. The shell in this genus is long and turreted, with convex whorls, which have no spiral band, while the surface is covered with longitudinal, often more or less arched threads or ridges. *Macrocheilus* (fig. 396) includes thick smooth shells, with convex whorls, an oval, not distinctly notched aperture, a callous inner lip, and an imperforate columella. The genus is mainly or exclusively Devonian and Carboniferous, and no Secondary or Tertiary forms have been detected, though a living Japanese shell has been referred here. The Carboniferous *Orthonema* is allied to *Loxonema,* and the *Soleniscus* of the same formation probably also belongs to this family, though it has affinities with *Fasciolaria.*

Fam. 9. Cerithiadæ. — Shell spiral, turreted; aperture channelled in front, with a less distinct posterior canal. Lip generally expanded in the adult. Operculum horny and spiral. The *Cerithiadæ* are exclusively confined to the

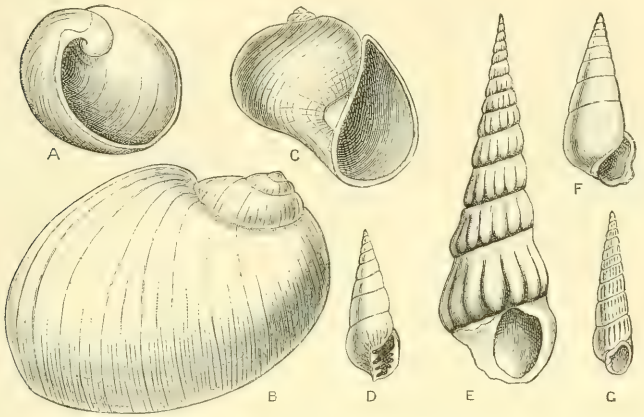


Fig. 397.—A, *Sigaretus clathratus*—Eocene; B, *Naticopsis plicistria*—Carboniferous (after M'Coy); C, *Narica Genevensis*—Cretaceous (after Pictet); D, *Pyramidella leviuscula*—Pliocene (after Searles Wood); E, *Loxonema rugifera*—Carboniferous (after Phillips); F, *Eulima vagans*—Jurassic (after Morris and Lycett); G, *Chemnitzia internodula*—Eocene (after Searles Wood).

Secondary, Tertiary, and Recent periods, and are represented in the Tertiary rocks by a vast number of forms. The most important fossil forms belong to the genera *Cerithium*, *Potamides*, *Nerinæa*, and *Aporrhais*, of which *Nerinæa* is extinct, and is exclusively confined to the Secondary period.

For all practical purposes *Cerithium* and *Potamides* may be considered together, as no strict line of demarcation can be drawn between the fossil forms. In both, the shell is turreted and many-whorled (fig. 398), with or without varices.

The aperture of the shell is small, with a tortuous anterior canal, and an expanded outer lip. Most of the living forms are inhabitants of fresh or brackish waters, and they are chiefly found in hot climates. The fossil forms, to the number of nearly five hundred, commence in the Trias, but they attain their maximum of development in the Eocene Tertiary.

In the genus *Nerinæa* (figs. 399 and 400) the shell is turreted, many-whorled, and nearly cylindrical. The columella carries continuous ridges, and similar ridges exist on the

Fig. 398.—*Cerithium hexagonum.* Eocene Tertiary.

Fig. 399.—*Nerinæa bisulcata.* Chalk.

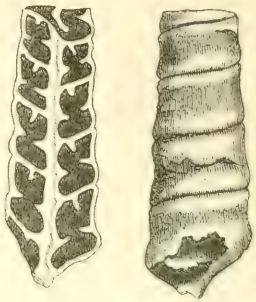


Fig. 400.—*Nerinæa Goodhallii*, one-fourth of the natural size. The left-hand figure shows the appearance presented by the shell when vertically divided. Coral Rag, England.

interior of the whorls, so that casts of the interior of the shell are often very unlike the form of the exterior. The aperture of the shell is channelled in front. The species of *Nerinæa* are exclusively Jurassic and Cretaceous, and are very numerous. One of the limestones of the Jura, believed to be of the age of the Coral Rag (Middle Oolite) of Britain, abounds to such an extent in these shells as to have gained the name of "Calcaire à Nérinées."

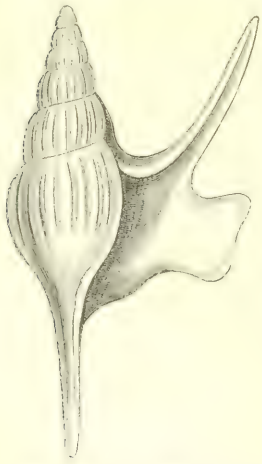


Fig. 401.—*Aporrhais Parkinsoni.* Cretaceous. (After J. Starkie Gardner.)

With the preceding may be associated the Secondary genera *Eustoma, Exclissa, Fibula, Cryptoplocus,* and *Ceritella,* and the Tertiary, *Quoyia* and *Mesostoma.*

The genus *Aporrhais,* with various related forms, constitutes a distinct group, with strong alliances with the *Strombidæ,* and often raised to the rank of a distinct family (*Aporrhaidæ*). The shell in *Aporrhais* (fig. 401) is

spindle-shaped, with a turreted spire, the outer lip of the adult being greatly expanded and lobed. Owing to the development of a well-marked anterior canal, and often of an equally conspicuous posterior tube as well, the shell becomes distinctly "siphonostomatous," and the genus should probably be placed in the immediate vicinity of *Pteroceras* and *Rostellaria*. The entire group makes its first appearance in the Jurassic period, attained its maximum in the Cretaceous, decreased in number in the Tertiary, and is represented by a few forms at the present day.

Fam. 10. Melaniadæ.—Shell spiral, turreted; aperture often channelled or notched in front; outer lip acute. Operculum horny and spiral. Many fossil shells have been referred to the *Melaniadæ*, but it is probable that most of these belong to the Palæozoic genus *Loxonema* and the Mesozoic *Chemnitzia*. Various forms of *Melania* have been described from the later Secondary rocks, and the genus is well represented in the Tertiary period, as are also the allied *Melanopsis* and *Gyrotoma*. All the living species inhabit fresh water, generally in the warmer parts of the world; and it is probable that all the fossil species occur only in fluviatile and lacustrine deposits.

Fam. 11. Turritellidæ.—Shell tubular or spiral, often turreted; upper part partitioned off; aperture simple. Operculum horny, many-whorled. Foot very short. Branchial plume single. The *Turritellidæ* are not known to have existed in the Palæozoic period; but they appear to commence about the middle of the Jurassic period, abounding in the Tertiaries, and attaining their maximum in existing seas. The chief fossil genera are *Turritella*, *Vermetus*, and *Scalaria*.

In *Turritella* (fig. 402) the shell is turreted, many-whorled, and spirally striated; the aperture is small and rounded, and the peristome thin. Species of *Turritella* have been described from the Palæozoic and older Mesozoic formations, but almost certainly belong to the genera *Murchisonia* and *Loxonema*. The genus is for the first time represented with certainty in the Lower Cretaceous rocks (Neocomian), and many fossil species are found in the Tertiaries.

The genus *Vermetus* comprises tubular shells, the chief interest of which is the strong resemblance which they show

Fig. 402.—*Turritella angulata.* Neocomian.

Fig. 403. — *Siliquaria anguina.* Pliocene and Recent.

Fig. 404. — *Scalaria Grenlandica.* Post-Pliocene and Recent.

to the Annelidous genus *Serpula.* The shell is attached, and though regularly spiral when young, is always irregular in its growth when adult. The fossil species are best distinguished from *Serpula* by the fact that the tube is repeatedly partitioned off by calcareous septa as the animal grows. It is, however, often a matter of extreme difficulty to determine whether a given specimen be a *Vermetus* or a *Serpula.* Fossil *Vermeti* are known from the Lower Cretaceous upwards. *Siliquaria* (fig. 403), dating from the Eocene Tertiary, resembles *Vermetus* in most respects, but the tube has a continuous longitudinal slit. These two forms are often regarded as a separate family (*Vermetidæ*). In *Cæcum,* again, also often looked upon as forming with some allied types a distinct family (*Cæcidæ*), the shell is at first discoidal, but becoming decollated with age, has the form of a curved cylindrical tube when adult. The genus commences in the Eocene Tertiary.

The genus *Scalaria,* comprising the Wentletraps, is the type of another group now commonly looked upon as a distinct family (*Scalidæ* or *Scalaridæ*), the characteristics of the section being the possession of a spiral and turreted shell, usually marked with longitudinal ribs, and having the aperture round and with an entire margin. In *Scalaria* (fig.

404) itself the shell is very like that of *Turritella*, but the whorls are ornamented with transverse ribs, and the peristome is continuous round the circular aperture. The *Scalariæ* commence in the Middle Oolites (Coral Rag), and attain their maximum in existing seas. *Cochlearia*, of the Trias, differs from the preceding chiefly in its expanded peristome. We may also place here, provisionally at any rate, the genus *Holopella*, which resembles *Scalaria* in general form and in the characters of the peristome, but in which the longitudinal ribs are reduced to mere striæ. The genus is principally Palæozoic, commencing in the Silurian; but it is said to occur in the Trias. The Palæozoic *Holopea* seems to have the entire aperture of the *Scalidæ*, but there are other features in which it resembles both the *Naticidæ* and *Littorinidæ*, and it will be here temporarily placed in the latter family.

Fam. 12. Littorinidæ.—Shell spiral, top-shaped, or depressed; aperture rounded and entire, operculum horny and pauci-spiral. The exact range of the *Littorinidæ* in time is uncertain, owing to the difficulty of determining the true affinities of many fossil univalves. Several Palæozoic and Mesozoic shells have been referred to *Littorina*, and the genus *Rissoa* commences in the Permian. The family, however, is mainly characteristic of the Tertiary and Recent periods. We may, nevertheless, consider here a number of more or less important Palæozoic genera, some of which seem undoubtedly to belong to the *Littorinidæ*, while others very probably do so, or, at any rate, do not possess decisive points of relationship with other families. The *Littorinidæ* may be divided into three groups, sometimes regarded as distinct families, and typified by the genera *Littorina*, *Solarium*, and *Rissoa*.

In the genus *Littorina* are the true Periwinkles, distinguished by their thick, generally top-shaped and pointed shells, of few whorls, and with an imperforate columella. The undoubted fossil species range from the Cretaceous to the present day.

We may also provisionally place near *Littorina* the Palæozoic genera *Holopea* and *Platyostoma*. The former is

Silurian and Devonian, and includes thin, conical, often smooth shells, with an expanded body-whorl (fig. 405). The mouth of the shell is entire, and the peristome seems to be sometimes complete, as in the *Scalaridæ*. The Devonian *Isonema* has angular whorls and a rhombic mouth, but in other respects resembles *Holopea*. In the Silurian and Devonian *Platyostoma*, again, the body-whorl is immensely expanded. Lastly, the genus *Cyclonema*, ranging from the base of the Silurian to the top of the Devonian, has a conical shell, which is characterised by the possession of fine spiral striæ, often with transverse striæ as well.

Fig. 405. — *Holopea Guelphensis.* (Billings.) Middle Silurian.

In the genus *Solarium*, comprising the "Staircase Shells," the shell (fig. 406) is much depressed; there is a large and deep umbilicus, running from the base to the apex of the shell; and the aperture is rhombic. The edge of the umbilicus is, typically, crenulated; and the shell is not pearly within. The genus appears in the Secondary period, is represented by undoubted species in the Cretaceous, is not uncommon in the Tertiaries, and survives at the present day. *Bifrontia*, Eocene and Recent, has the body-whorl free. *Phorus* (fig. 407) comprises trochoid shells, with a concave base and flattened whorls. Very usually foreign bodies, such as shells or small pieces of stone, are attached to the surface and margins of the shell. There is considerable uncertainty as to the geological range of the genus, species having been described from deposits as old as the Devonian; but the first undoubted forms occur in the Jurassic, and there are various Tertiary and living types. We may also place here the genus *Cirrus* (fig. 408), in which the shell is discoidal and there is a large umbilicus; while the upper surface

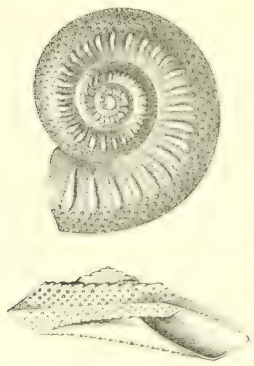


Fig. 406.—*Solarium ornatum.* Gault (Upper Cretaceous).

bears a row of spines, which in the neighbourhood of the aperture are tubular and have their ends perforated. The genus ranges from the Devonian to the Jurassic.

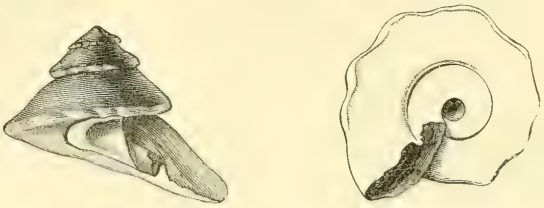


Fig. 407.—*Phorus canaliculatus.* Cretaceous.

In accordance with the views now most generally accepted, we must also place here the important and widely-distributed Palæozoic genus *Euomphalus,* with its allies.

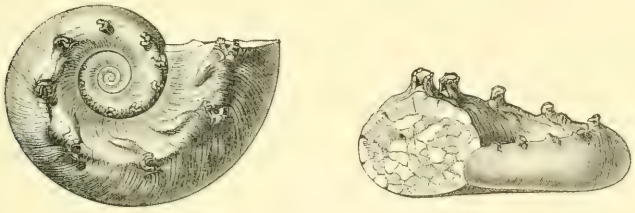


Fig. 408.—*Cirrus Goldfussi.* Devonian.

The genus *Euomphalus* (figs. 409, 410) is entirely extinct, and is essentially Palæozoic, ranging from the Silurian to the

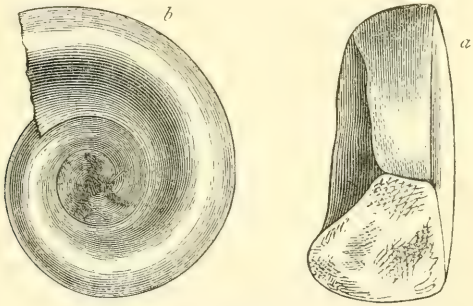


Fig. 409.—*Euomphalus De-Cewi* (Billings). *a*, Front view; *b*, View of the umbilicus. Devonian.

Trias, but being most abundant in the Carboniferous rocks. The shell in this genus is depressed or discoidal, the whorls

lying nearly or quite in the same plane. The whorls are angulated or coronated, the aperture is polygonal, the umbilicus is very large, and there is a shelly operculum.

The genus *Straparolus* (or *Straparollus*) is closely related to *Euomphalus*, and, strictly speaking, is probably identical with it. It is convenient, however, to retain both names, employing that of *Euomphalus* for the forms with a depressed discoidal shell, with angular whorls and an open umbilicus (fig. 410); while the title *Straparolus* may be applied to those with rounded non-angulated whorls, a small umbilicus, and a more or less prominent spire. *Euomphalopterus*, of the Upper Silurian, includes forms allied to *Euomphalus*, but having winged whorls, the alation being perforated by canals which open internally into the cavity of the shell, and externally by minute pores on the margin of the wing. *Straparollina*, again, includes Palæozoic shells, believed to stand midway between *Straparolus* and *Holopea*. The shells which have been described under the names of *Raphistoma*, *Ophileta*, and *Helicotoma*—principally or exclusively Lower Silurian in their range—are apparently closely allied to *Euomphalus*, if, indeed, they are really separable from it. Lastly, some palæontologists would place here the singular genus *Maclurea*, which, however, is perhaps best regarded as one of the Heteropods; and we shall also temporarily consider *Ophileta* as belonging to the same group.

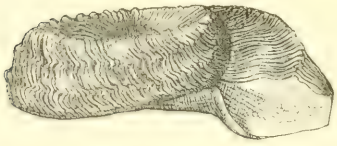


Fig. 410.—*Euomphalus discors*. Upper Silurian, Britain.

Finally, we have a group of *Littorinidæ* typified by the genus *Rissoa* (fig. 411), in which the shell is small, pointed, and many-whorled, with a small round aperture surrounded by a continuous peristome. Many fossil species are known, commencing in the Permian; and the genus is universally distributed at the present day. Among the allies of *Rissoa*, *Rissoina* appears first in the Jurassic, *Keilostoma* is found in the Cretaceous and Eocene beds, and *Diastoma* and *Pterostoma* are Eocene types.

Fam. 13. Paludinidæ.—Shell conical or globular; aperture rounded and entire; operculum horny or shelly. The *Paludinidæ* are essentially inhabitants of fresh water; though they sometimes live in brackish, or even in salt water. As a matter of course, therefore, they are chiefly, if not exclusively, found as fossils in deposits which are believed to be fluviatile or lacustrine in their origin. The three chief living genera are, *Paludina* (fig. 411, B), *Valvata* (fig. 411, C), and *Ampul-*

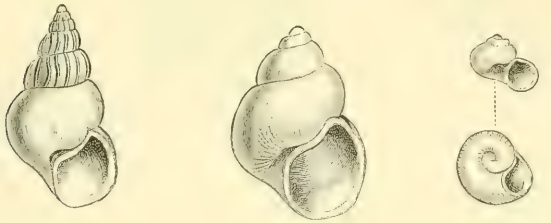


Fig. 411.—A, *Rissoa supracostata*—Pliocene, enlarged six times; B, *Paludina lenta*—Pliocene; C, *Valvata piscinalis*, viewed from in front and from below—Pliocene. (After Searles Wood.)

laria. The two former date from the Cretaceous period, the first possibly from the Jurassic, and both abound in the Wealden and in many Tertiary deposits. *Bithynia* resembles *Paludina*, but the operculum is shelly. *Valvata* may be top-shaped or discoidal, but the shell is umbilicated, and the peristome is entire. The existence of *Ampullariæ* in a fossil state is attended with considerable uncertainty, chiefly from the great difficulty, or impossibility, of separating them from species of the marine genus *Natica*.

Fam. 14. Neritidæ.—Shell thick, globular, with a very small spire; aperture semi-lunate, its columellar side expanded; outer lip acute. Operculum shelly, sub-spiral. The *Neritidæ* are not known as occurring in the Palæozoic rocks, but are found from the Jurassic period onwards, attaining their maximum at the present day.

In the genus *Nerita* (fig. 412) the shell is thick, with a broad columella, the inner edge of which is straight and toothed. The outer lip is thickened and often denticulated internally. The true Nerites are inhabitants of warm seas;

and they date in past time from the Lias. The nearly-allied genus *Neritina* includes the so-called "fresh-water Nerites," which agree in most characters with *Nerita*, but inhabit fresh or brackish waters, and have a comparatively thin smooth

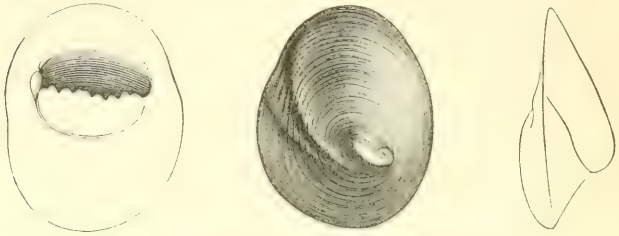


Fig. 412.—*Nerita Schmidelliana.* Eocene Tertiary.

shell. The fossil species commence in the Eocene Tertiary. The Jurassic genus *Neritoma* has a thick ventricose shell, with a notch in the middle of the outer lip. *Neritopsis*, again, commences in the early portion of the Secondary period, and still survives. Its shell is distinguished by the possession of a single notch in the middle of the inner lip. In connection with this genus we must mention the curious Jurassic fossils which have been described under the name of *Peltarion*. These are oval or nearly circular calcareous plates, concave above and flattened below; and they have generally been regarded as the mandibles of Tetrabranchiate Cephalopods. Recent researches, however, seem to show that these singular bodies are really the opercula of species of *Neritopsis*.

Lastly, the genus *Pileolus* comprises small limpet-shaped shells, with a semi-lunar aperture below. The only known fossil species are from the Lower Oolites (Great Oolite).

Fam. 15. Turbinidæ.—Shell turbinated (top-shaped) or pyramidal, nacreous (*i.e.*, pearly) inside. Operculum horny and multi-spiral, or calcareous and pauci-spiral. The family of the *Turbinidæ* has a high antiquity, the forms ascribed to it dating from the Lower Silurian; but many of the older shells referred to this family are of more or less doubtful affinities.

In the genus *Turbo* (fig. 413) the shell is turbinated, with

a round base. The whorls are convex; the aperture is large and rounded; and the operculum is calcareous. A great number of fossil species of this genus have been described, commencing in the Lower Silurian; but there is considerable doubt as to the true position of many of the older forms.

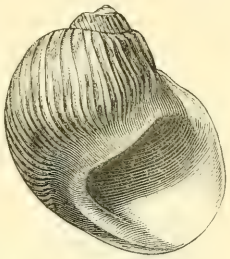


Fig. 413.—*Turbo subcostatus.* Devonian.

In the genus *Trochus* (fig. 414, A) the shell is pyramidal, with a nearly flat base; the aperture is oblique and rhombic in shape, and the operculum is horny. A great number of species of this genus, also, have been described, commencing in the Silurian rocks. As in the case of *Turbo*, however, the affinities of many of the older forms are very problematical.

Phasianella (fig. 414, B) is in many respects like *Turbo*, but the shell is elongated, with an oval aperture, and a smooth and polished surface. Its precise range in past time is uncertain, but undoubted examples occur in the Jurassic and Cretaceous rocks. *Monodonta* in its general characters resembles *Trochus*, but the columella is thickened, toothed, and crenulated. The genus ranges from the Tertiary period to the present day, and doubtful representatives of it have been indicated as occurring in older times. In *Delphinula* the shell is orbicular and depressed, the whorls angulated or coronated, often spiny, the mouth round, the peristome entire, and the umbilicus open. The genus seems to begin in the Trias. Lastly, *Stomatella*, commencing in the Secondary period, has an ear-shaped shell, with a small spire, and a very wide oblique aperture.

Fam. 16. Haliotidæ. — Shell spiral, ear-shaped, or trochoid; aperture large, nacreous. Outer lip notched or perforated. No operculum. Mantle-margin with a posterior fold or siphon, occupying the slit or perforation in the shell.

The living genera *Haliotis* and *Scissurella* are not known in rocks older than the Miocene Tertiary. The extinct genera *Pleurotomaria* and *Murchisonia* are, on the other hand, of

great antiquity, the latter being exclusively Palæozoic, and the former mainly so.

The genus *Haliotis* (fig. 414, c) comprises the so-called "Ear-shells," distinguished by their ear-shaped shell, with a

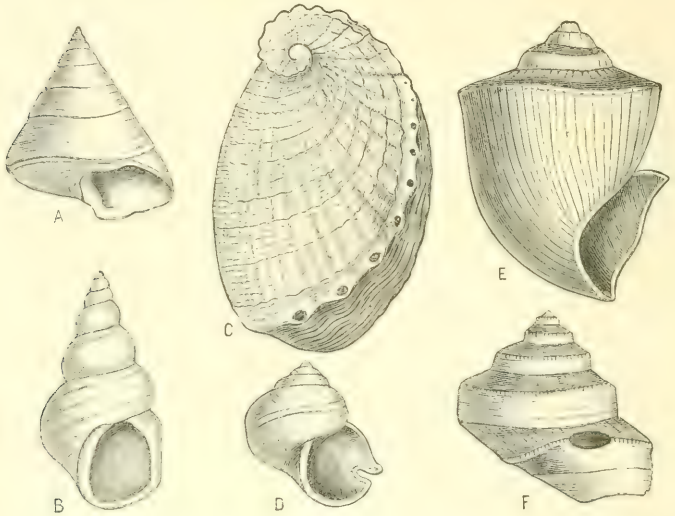


Fig. 414.—A, *Trochus conulus*—Pliocene; B, *Phasianella melanoides*—Eocene; C, *Haliotis tuberculata*—Pliocene; D, *Scissurella aspera*—Pliocene; E, *Scalites angulatus*—Lower Silurian; F, *Trochotoma affinis*—Jurassic. (After Searles Wood, Deshayes, Pictet, Philippi, and Hall.)

minute spire, an enormous aperture, and a series of round perforations in the outer angle of the shell. A few fossil species are known, commencing in the Miocene.

Stomatia is allied to *Haliotis*, but the spire is prominent, and the place of the perforations in the shell is taken by a furrow. The genus forms a transitional link between the families *Haliotidæ* and *Turbinidæ*, and is represented by living forms, the earliest types ascribed to it dating from the Devonian.

In the genus *Scissurella* (fig. 414, D), which also commences in the Miocene, the shell is thin, with a large and greatly expanded body-whorl, and the place of the perforations of *Haliotis* is taken by a simple slit in the margin of the outer lip.

The genus *Pleurotomaria* comprises a great number of Palæozoic univalves, which occur in the Silurian, Devonian, and Carboniferous formations. In sediments later than the Carboniferous the genus is largely represented, extending even to the close of the Mesozoic period. In the Jurassic period especially the genus has a great development, most of the forms being more ornate than those from the older rocks. In the Cretaceous rocks various species of the genus still appear, but very few Tertiary forms are known, and only two living species have been as yet detected. The form of the shell in *Pleurotomaria* (figs. 415, 416) differs considerably in different cases. Very commonly the shell is very similar to that of *Trochus*. In other cases it more nearly resembles *Turbo;* and sometimes it is very much flattened out and depressed. The shell consists of few whorls, of which the last may be disconnected from the others, and is essentially distinguished by its subquadrate aperture, with a deeper or shallower slit in the outer lip. As the shell grows, this slit becomes progressively filled up, forming a well-marked band on the whorls. By this character *Pleurotomaria* may generally be distinguished readily from such shells as *Trochus* and *Turbo*.

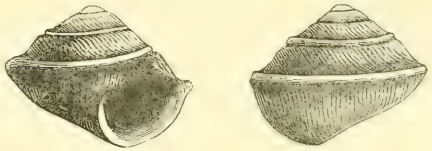


Fig. 415.—*Pleurotomaria Agave.* Lower Silurian. (Billings.)

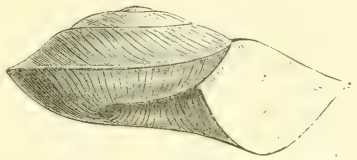


Fig. 416.—*Pleurotomaria Dryope.* Lower Silurian. (Billings.)

Many subordinate types are included in the comprehensive genus *Pleurotomaria*, in the wide sense. Thus a number of Secondary types admit of separation from *Pleurotomaria* proper by their possession of a very deep slit and a narrow band, and these may be grouped together under the name of *Leptomaria*. In the Carboniferous *Polytremaria* the band on the whorls is perforated by a linear series of minute foramina.

In the Jurassic *Ditremaria* there is a kidney-shaped aperture, consisting of two foramina united by a slit, in the band near the outer lip. Lastly, in the Jurassic genus *Trochotoma*, the shell is trochoid, with a concave base, and there is a single elongated perforation in the band near the margin of the outer lip.

It would seem probable that the ancient Lower Silurian types which have been described under the names of *Scalites* and *Raphistoma* should be placed in the neighbourhood of *Pleurotomaria*. In *Scalites* (fig. 414, E) the shell is spiral, with a flattened spire, the body-whorl ventricose, the "suture" canaliculated, the lip truncated, and the columella imperforate and curved. In *Raphistoma* the spire is still more depressed, the "suture" is close, instead of being grooved, there is an umbilicus of moderate size, and the aperture is somewhat trigonal and slightly notched.

High authorities now also place here the genus *Porcellia* (fig. 417), and there are certainly strong grounds for accepting this view, though this type has usually been regarded as referable to the Heteropods, and it has unquestionable points of resemblance with the *Bellerophontidæ*. If we provisionally place *Porcellia* in this connection, we have to regard it as a discoidal *Pleurotomaria*, in which there is a dorsal band, in the median line, with a deep slit in the outer lip. This last feature is undoubtedly one which brings the genus in close connection with *Pleurotomaria;* and as some forms of the latter are very nearly discoidal, it is perhaps best to remove *Porcellia* from its association with the Heteropodous genus *Bellerophon*, in which the outer lip of the aperture is sinuated or notched, but not slit, and there is no dorsal band. So far as known, *Porcellia* is Devonian, Carboniferous, and Triassic in its range.

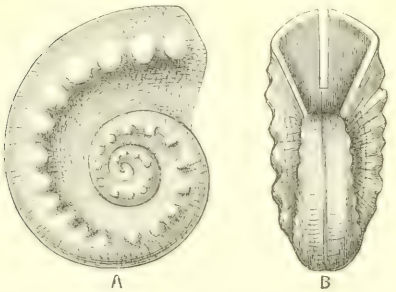


Fig. 417.—*Porcellia puzo*, viewed sideways (A) and from the front (B). Carboniferous.

Closely allied to *Pleurotomaria* is the important genus *Murchisonia* (fig. 418), which is exclusively confined to the Palæozoic period, ranging from the Lower Silurian to the Permian. The shell in *Murchisonia* closely resembles that of *Pleurotomaria*, but is usually more elongated and composed of a greater number of whorls. The outer lip is deeply notched, and the whorls have the same band on their exterior as is present in *Pleurotomaria*. The aperture of the shell is slightly channelled in front, and the surface is often variously sculptured and adorned.

Fig. 418. — *Murchisonia gracilis*. (Hall.) Lower Silurian.

Finally, we may include in the present family the living genus *Ianthina*, which in some respects may be regarded as the type of a distinct group. In this genus the shell is spiral and turbinate, with a thin translucent shell; and it is doubtful if any fossil forms can be definitely referred to it.

Fam. 17. Fissurellidæ.—Shell conical, patelliform, with a notch in the anterior margin, or a perforation at the apex, which is occupied by the anal siphon. Muscular impression horse-shoe-shaped, open in front. The existence of the *Fissurellidæ* in the Palæozoic period is open to considerable doubt; but a good many fossil forms are known from the Secondary and Tertiary rocks.

The genus *Fissurella* (fig. 419, a) comprises the so-called "Keyhole Limpets," distinguished by having the apex of the shell perforated by a larger or smaller, generally oval aperture. Doubtful examples of the genus have been indicated as occurring in the Devonian and Carboniferous; and there are a good many unequivocal species in the Secondary and Tertiary rocks. In the genus *Rimula* (fig. 419, b), ranging from the Trias to the present day, the perforation, instead of being at the apex of the shell, is placed a little above the anterior margin. Lastly, in *Emarginula* (fig. 419, c) the anterior margin is furnished with a longitudinal notch or slit. The species of this genus date from the Trias.

Fam. 18. Calyptræidæ. — Shell limpet-shaped, with a more or less spiral apex; interior simple, or divided by a shelly process to which the adductor muscles are attached. With the exception of the persistent genus *Capulus*, it is

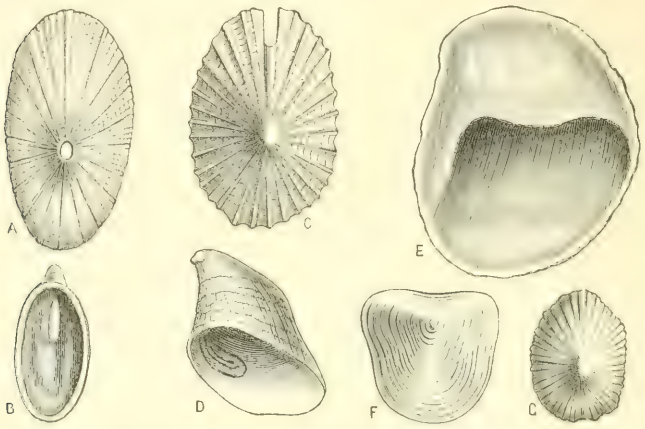


Fig. 419.—Fissurellidæ, Calyptræidæ, and Patellidæ. A, *Fissurella labiata*—Eocene; B, *Rimula Blainvillei*—Eocene; C, *Emarginula Guerangueri*—Cretaceous; D, *Hipponyx cornucopiæ*—Eocene; E, *Crepidula costata*—Miocene; F, *Metoptoma imbricata*—Carboniferous; G, *Patella costaria*—Eocene.

doubtful if any of the *Calyptræidæ* are to be found in the Palæozoic rocks. They are by no means abundant in the Secondary formations; and though more plentiful in the Tertiaries, they attain their maximum in existing seas.

The genus *Calyptræa* includes the so-called "Cup-and-saucer Limpets," in which the interior has a half-cup-shaped process attached to the apex of the shell, and open in front. With doubtful exceptions, the fossil species of *Calyptræa* are all of Tertiary age. In the genus *Crepidula* (fig. 419, E) there is a shelly partition covering the posterior half of the interior of the shell. The fossil species date from the Eocene Tertiary.

Hipponyx (fig. 419, D) comprises thick and obliquely conical shells, with a posterior apex, and provided with a shelly basis marked by a distinct horse-shoe-shaped muscular impression. The genus ranges from the Cretaceous period to the present day.

By far the most important genus of this family, palæontologically speaking, is that to which the names of *Capulus, Pileopsis, Acroculia,* and *Platyceras* have been applied. Of these names, the last has been, and is still, very widely used by American palæontologists, but no valid distinction has yet been pointed out between this and *Capulus,* and as the latter has the priority over all the titles above mentioned, it will be employed here. In the genus *Capulus* the shell is conical, with a posterior sub-spiral apex, and a horse-shoe-shaped muscular impression. The aperture is greatly enlarged, and its margins are essentially entire; but owing to the fact that the shell is usually affixed for lengthened periods to foreign bodies, the lips may become more or less sinuated or undulated (figs. 420, 421). The shells of this genus may, as a rule, be recognised by their obliquely-spiral or straight conical shape, their wide aperture, and the absence of a columella. They may be dextral or sinistral, and the surface may be simply marked with concentric lines of growth, or may be ornamented with spines. The genus is abundantly represented in the Silurian and Devonian periods, and less abundantly in the Carboniferous. Many Secondary and Tertiary species are known, and the comparatively few living species are widely distributed over the globe.

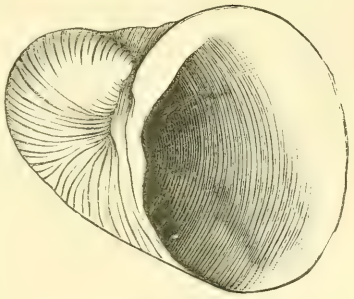


Fig. 420.—*Capulus* (*Platyceras*) *ventricosus.* Upper Silurian. (After Hall.)

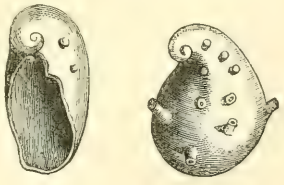


Fig. 421.—Different views of *Capulus* (*Platyceras*) *dumosus,* of the natural size. Devonian, Canada. (Original.)

Fam. 19. Patellidæ. — Shell conical, with the apex turned forwards; muscular impression horse-shoe-shaped, open in front. Foot as large as the margin of the mantle. Respiratory organ in the form of one or two branchial plumes, lodged

in a cervical cavity, or of a series of lamellæ surrounding the animal between the body and the mantle. The *Patellidæ* commence to be represented in the Lower Silurian rocks, and have continued to the present day.

The genera *Patella* (including the common Limpets), *Acmæa*, and *Metoptoma* can with difficulty be separated in practice from one another by their shells alone. *Patella* (fig. 419, G) and *Acmæa*, at any rate, are palæontologically indivisible, since the only distinctions between them are in the nature of the respiratory organs. Including these genera, therefore, in one, the range of the Limpets is from the Silurian upwards.

Some of the Upper Cambrian Limpets have been separated under the name of *Palacmæa*, but the differences between these and *Patella* proper appear to be slight.

The genus *Metoptoma* (figs. 419, F, and 422) very closely

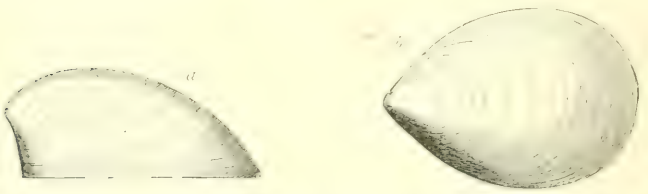


Fig. 422.—*Metoptoma nycteis*. *a*, Side view; *b*, View of the upper side. Lower Silurian. (Billings.)

resembles *Patella*, but the muscular scar consists of a number of disconnected cavities. In the typical species, also, the anterior side, under the apex of the shell, is truncated or nearly straight. Species of *Metoptoma* are particularly abundant in the Lower Silurian series; but they range as far as the Carboniferous. It may be doubted, however, if some of the so-called *Metoptomæ* are not really the posterior plates of Chitons.

Fam. 20. Dentalidæ.—Shell tubular, symmetrical, curved, open at both ends. Aperture circular. Foot pointed, with symmetrical side-lobes. The "Tooth-shells" are generally placed here, in the vicinity of the Limpets; but they are referred by Huxley to the class of the *Pteropoda*. The family comprises the principal genus *Dentalium*, in the wide sense

of this name, well known by the tubular, smooth, or longitudinally-striated shell, open at both ends (fig. 423). The fossil species are liable to be confounded with the tubes of Tubicolar Annelides, or a reverse mistake to this may be made. Several species have been described from the Devonian, and more especially from the Carboniferous rocks, some of them of large size; but more or less doubt obtains as to the true nature of some of these. The Secondary rocks have yielded a considerable number of species, and they become still more numerous in the Tertiaries. It does not seem impossible that some of the so-called forms of *Theca* (*Hyolithes*), from the Silurian and Upper Cambrian, may really prove to be referable to *Dentalium*. The genus *Gadus*, ranging from the Cretaceous to the present day, is separable from *Dentalium* chiefly by the characters of the animal itself, but the shell in the former is small, and has a contracted anterior extremity and a polished surface.

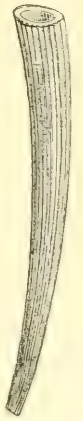


Fig. 423.—*Dentalium Bouei*. Miocene. (After Deshayes.)

Fam. 21. Chitonidæ. — Shell multivalve, composed of eight transverse plates, disposed one behind the other in an imbricated manner. Animal with a broad creeping foot; branchiæ forming a series of lamellæ between the foot and the mantle, round the posterior part of the body. The *Chitonidæ* comprise only the single genus *Chiton*, with several more or less distinct sub-genera. The species of the family commence in the Lower Silurian, and are rare as fossils, attaining their maximum at the present day.

Fig. 424. — *Helminthochiton Griffithii*. Silurian. (After Salter.)

The distinctive peculiarities of the shell of the Chitons (fig. 424), by which they may always be separated from the Cirripedes, are the following: 1. The shell never consists of more or fewer than eight pieces. 2. The valves of the shell are always placed one behind the other in a unilinear series. 3. The six middle plates of the shell are divided, each, by lines of sculpturing into three distinct areas

—a dorsal and two lateral areas. 4. Each plate is embedded in the mantle of the animal by forward extensions of its front edge, which are termed the "apophyses."

The Chitons are represented by fossil species in the Silurian, Devonian, Carboniferous, and Permian rocks, and are not so excessively rare in the Carboniferous Limestone. They are very poorly represented in the Secondary rocks, and are by no means abundant in the Tertiaries.

Order II. Opisthobranchiata.—*Gills placed towards the rear of the body.*

Fam. 22. Tornatellidæ.—Shell external, spiral or convoluted; aperture long and narrow; columella plaited. The *Tornatellidæ* are mainly Mesozoic, the fossil forms ranging from the Trias or from the base of the Jurassic series to the Chalk inclusive, and attaining their maximum in the Cretaceous series. Several genera are entirely extinct, of which the most important is *Cinulia* (fig. 425). In this genus the shell is globular, with a small spire, the outer lip reflected and crenulated interiorly, and the columella with tooth-like folds. All the species are Cretaceous. In the genus *Tornatella*, the shell is ovate, with a well-marked spire, the outer lip thin, and the columella with a strong fold. The fossil species range from the Trias upwards, and the genus, though on the decline, is represented by several living species. Many of the Secondary species belong to more or less distinct groups (*Cylindrites*, *Acteonella*, and *Acteonina*).

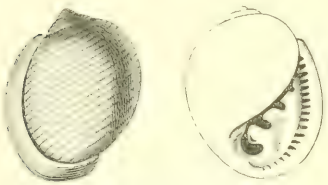


Fig. 425.—*Cinulia avellana* (*Avellana cassis*—D'Orbigny). Chalk.

Fig. 426.—*Bulla suprajurensis*. Middle Oolites.

Fam. 23. Bullidæ.—Shell convoluted, thin; spire small or concealed; lip sharp. Animal often more or less completely investing the shell. The *Bullidæ* commence their existence in the Triassic period, and have continued to the present day. The most important genus is *Bulla*, comprising the so-called "Bubble-shells" (fig. 426). The species of this

genus are not uncommon in the fossil condition, commencing in the Oolites. *Cylichna*, beginning in the Trias, is well represented in later deposits.

Fam. 24. Aplysiadæ.—Shell absent or rudimentary, concealed by the mantle when present. Animal slug-like; sides extensively lobed and reflected over the back and shell. One or two shells from the younger Tertiary rocks have been referred, with great doubt, to the genus *Aplysia*.

Fam. 25. Pleurobranchidæ.—Shell limpet-like or concealed, rarely wanting. Mantle or shell covering the back of the animal. Two doubtful species belonging to the genus *Umbrella* have been described from the Tertiaries; but the family is otherwise unknown in the fossil condition.

CHAPTER XXV.

GASTEROPODA (Continued).

Heteropoda and Pulmonifera.

Order III. Heteropoda, or Nucleobranchiata.—The Gasteropods of this order differ from the typical members of the class in being *organised to lead an existence in the open ocean, locomotion being effected by a fin-like tail, or by a fan-shaped vertically-flattened ventral fin.* They are found swimming at or near the surface of the ocean; and the body may be completely protected by a shell, within which the animal can retire, and which can be closed by an operculum. In other cases, as in *Carinaria* (fig. 427), the body is large, and

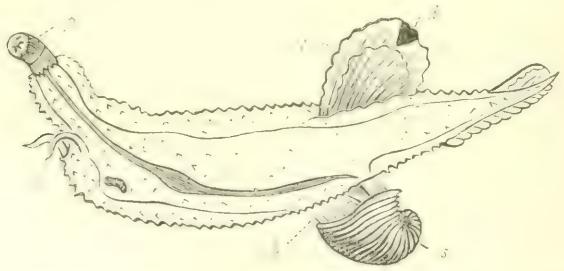


Fig. 427.—Heteropoda. *Carinaria cymbium.* *p*, Proboscis; *t*, Tentacles; *b*, Branchiæ; *s*, Shell; *f*, Foot; *d*, Disc. (After Woodward.)

there is only a small shell protecting the gills and heart. In other cases, again, the shell is completely wanting. The order is divided into the two families of the *Firolidæ* and

Atlantidæ. The former of these is represented by a single species only, from the Miocene Tertiary. The latter had a great development in Palæozoic seas, and is represented in the formations of this period by several remarkable genera.

Fam. 1. Firolidæ.—Body large, never completely protected by a shell, often shell-less. Sometimes a small delicate hyaline shell, placed on the back, protecting the gills. The only genus of this family which is known to be certainly represented in a fossil state is *Carinaria* (fig. 427), a single species of which has been found in deposits of Tertiary age (Miocene).

Fam. 2. Atlantidæ.—Animal furnished with a well-developed shell, into which it can retire. Shell symmetrical, discoidal, destitute of septa, often provided with an operculum. This family is represented by the genera *Bellerophon, Maclurea, Cyrtolites, Ecculiomphalus*, &c., most of which are exclusively Palæozoic, whilst the others are mainly so.

In the genus *Bellerophon* (fig. 428) the shell is symmetri-

Fig. 428.—*Bellerophon Argo* (Billings). *a*, Front view; *b*, Side view. Lower Silurian.

cal, convoluted, the coils of the shell usually lying in one plane. The whorls are few, smooth or sculptured, and there is a dorsal keel along the convex margin of the shell. The aperture is often more or less expanded, and is in most instances emarginate or deeply notched on the dorsal side. The genus ranges from the Lower Silurian to the Carboniferous. The *Bellerophina* of the Gault (Upper Cretaceous) is doubtfully allied to *Bellerophon*, and may belong to the *Pteropoda*. *Bucania*, of the Silurian, includes forms not generically separable from *Bellerophon*, but distinguished by the fact that all the volutions are visible and increase in

size gradually towards the mouth. *Tremanotus*, of the same formation, has a dilated aperture, and possesses a row of separate oval apertures along the dorsal side. The *Bellerophontidæ* are sometimes placed among the *Haliotidæ*, and the genus *Porcellia*, often regarded as Heteropodous, has been here considered as an ally of *Pleurotomaria*.

The genus *Maclurea* is very remarkable in its structure, and all the known species are entirely confined to the Lower Silurian rocks. The shell (fig. 429) in this singular genus is "discoidal, few-whorled, longitudinally grooved at the back, and slightly rugose with lines of growth; dextral side convex, deeply and narrowly perforated; left side flat, exposing the inner whorls; operculum sinistrally sub-spiral, solid, with two internal projections, one of them beneath the nucleus, very thick and rugose" (Woodward). *Maclurea* has been variously regarded as "dextral" or "sinistral;" but the probabilities are in favour of the view that it is truly *dextral*. In this case, the flat side of the shell is the umbilicus, and the spire must be regarded as sunk below the general surface of the shell. (On this view the specimen figured at *b*, fig. 429, is represented upside down.) The species of *Maclurea* occur chiefly at the base of the Lower Silurian series both in North America and in Scotland, occurring in some localities in the greatest profusion.

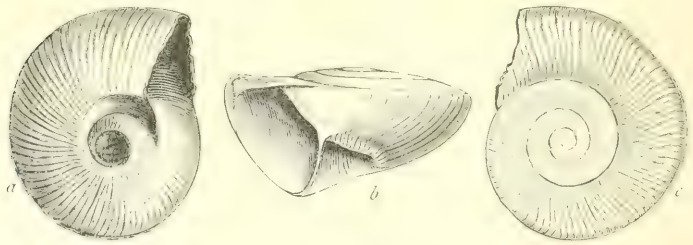


Fig. 429.—*Maclurea crenulata*. *a*, Spire; *b*, Front; *c*, Base. Lower Silurian.

The genus *Ophileta* (fig. 430), of the Silurian rocks, may be mentioned here, though its true affinities are extremely doubtful. The shell in this genus is discoidal, and very closely resembles that of *Euomphalus*. The aperture, however, is stated by Mr Billings to have a sinus in the lower

lip and a notch in the upper lip—characters which are not present in *Maclurea*. It is a matter of question whether *Ophileta* should be regarded as comprising species of *Maclurea* with slender whorls, or whether it should be placed in the *Littorinidæ*, in or near *Euomphalus*, as has been previously mentioned, or whether it should not be placed in the *Haliotidæ* and be regarded as a discoidal *Pleurotomaria*.

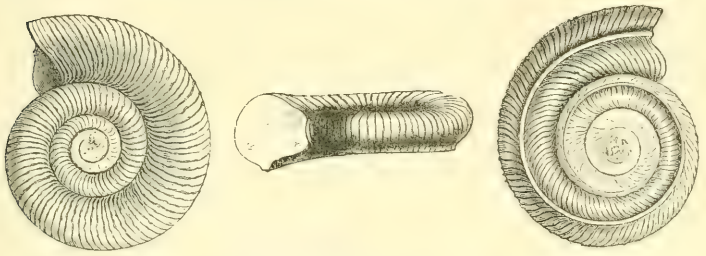


Fig. 430.—*Ophileta bella* (Billings). Different views of a nearly perfect specimen. Quebec Group (Lower Silurian).

In the genus *Cyrtolites* (fig. 431) the shell is thin, symmetrical, discoidal, or coiled into the shape of a horn, the whorls more or less disconnected, furnished with a keel, and sculptured. The species of this genus range from the Lower Silurian to the Carboniferous rocks, and are therefore exclusively Palæozoic.

Fig. 431.—*Cyrtolites ornatus*. Lower Silurian.

In *Ecculiomphalus* (fig. 432) the shell is very like that of *Cyrtolites*, but the whorls are few in number, and are widely separated from one another. The shell is thin, and the coils lie in the same plane. The species of this genus range from the Lower Silurian to the Carboniferous, and have been compared to *Euomphali* imperfectly rolled up; but the true affinities of the genus are doubtful.

Section B. Pulmonifera.—Respiration aerial, by means of a pulmonary chamber. The *Pulmonifera* include the ordinary Land-snails, Slugs, Pond-snails, &c., and are usually provided with a well-developed shell; though this may be rudimentary (as in the Slugs), or even wanting. In the

Land-snails and Pond-snails there is a well-developed shell into which the animal can retire completely. The Slugs, again, have a merely rudimentary shell which is completely concealed within the mantle. The completely shell-less forms

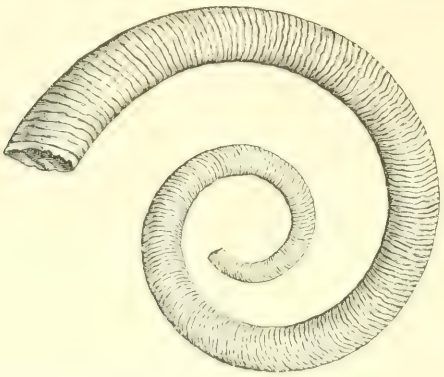


Fig. 432.—*Ecculiomphalus distans.* Quebec Group (Lower Silurian).

are necessarily wholly unknown as fossils. The Slugs, with a rudimentary shell, are only doubtfully represented in a fossil state, and that only in the Tertiary rocks. The abundance of the shell-bearing forms as fossils depends mainly on the habits of the animal. The Land-snails, being terrestrial in their habits, are, necessarily, but sparingly represented as fossils, and they do not date back to a time anterior to the Carboniferous. The Pond-snails, being exclusively confined to fresh water, are only known as fossils in fluviatile and lacustrine deposits, and they are exclusively Secondary and Tertiary, not being known in the Palæozoic period. The *Pulmonifera* are divided into the two orders of the *Inoperculata* and *Operculata*, according as the shell is destitute of an operculum, or is provided with this apparatus.

Order IV. Inoperculata.—*Shell not provided with an operculum.*

Fam. 1. Helicidæ.—Shell well developed, capable of containing the entire animal. With the exception of *Pupa*, *Dawsonella*, and *Zonites* (the last a sub-genus of *Helix*), all the *Helicidæ* belong to the Tertiary and Recent periods. As they are all terrestrial in their habits, they are necessarily

of rare occurrence as fossils, occurring chiefly in fluviatile and lacustrine deposits. The genera above mentioned have been found in the Coal-measures, and are the oldest forms of the group. The chief fossil genera are *Helix*, *Bulimus*, *Achatina*, *Pupa*, and *Clausilia*.

In the genus *Helix* are the ordinary Land-snails (fig. 433), in which the shell is conical, sometimes depressed, or sometimes discoidal; the aperture transverse, crescentic or rounded, and the columella perforated or imperforate. The Land-snails, with two exceptions, are all confined, so far as known, to the Tertiary and Recent periods. The exceptions to this statement are the *Zonites priscus* (fig. 433), discovered by Dr Dawson in the Coal-measures of Nova Scotia, and the *Daw-*

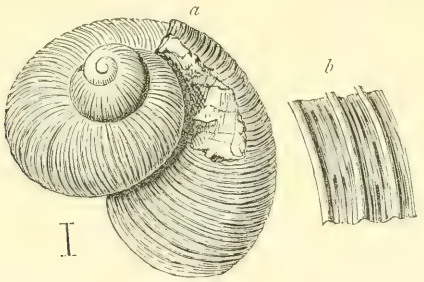


Fig. 433.—*Zonites* (*Conulus*) *priscus* (after Dawson). *a*, Specimen enlarged twelve diameters *b*, Sculpture, magnified. Coal-measures, Nova Scotia.

sonella Meeki of the same formation. The former is a true Land-snail referred to *Zonites* or *Conulus*, a sub-genus of *Helix* itself.

In *Bulimus* the shell is turreted or oblong, the columella generally simple, and the outer lip usually expanded and thickened. In the nearly allied genus *Achatina* the columella is twisted, and the lips of the shell-aperture are thin. Both genera date their existence from the Eocene Tertiary.

In the genus *Pupa* the shell is cylindrical or oblong, with a round, often toothed, aperture. The oldest member of this genus is the *Pupa vetusta* (fig. 434), discovered by Dr Dawson in the Coal-measures of Nova Scotia, in the hollow trunk of an erect *Sigillaria*. This ancient form is remarkably like some living "Chrysalis-shells," and there appears

to be no reason for framing a new genus (*Dendropupa*) for its reception. The *Pupa Vermilionensis* of the Coal-measures is a near ally of the preceding. With the exception of these little shells, all the fossil species of *Pupa* are confined to the Tertiary period, commencing in the Eocene.

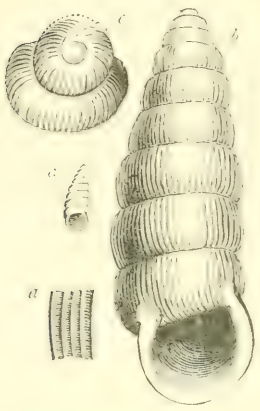


Fig. 434.—*Pupa* (*Dendropupa*) *vetusta* (after Dawson). *a*, Natural size; *b*, Enlarged; *c*, Apex enlarged; *d*, Sculpture, magnified. Coal-measures.

In the genus *Clausilia* the shell is spindle-shaped, coiled into a left-handed spiral ("sinistral"), with an elliptical aperture, partially contracted by shelly processes. The *Clausiliæ*, so far as known, date their existence from the Eocene Tertiary.

Fam. 2. Limacidæ. — Shell rudimentary, usually internal or concealed by the mantle. The "Slugs" are included in this family, and they are only known in the fossil state by doubtful remains in the Miocene and Pliocene Tertiary. A species of *Testacella* has also been indicated as occurring in the Miocene.

Fam. 3. Limnæidæ.—Shell well developed, thin, and horn-coloured. Aperture simple; lip sharp. The *Limnæidæ* are all inhabitants of fresh water, and they are found in fluviatile and lacustrine deposits. They are believed to commence in the Jurassic period, members of this family having been described from the Lias and from the Purbeck beds (Upper Oolites). It is not, however, until we reach the base of the Cretaceous system (Weald Clay) that these forms appear in any abundance.

Fig. 435.—*Limnæa pyramidalis*. Eocene.

The genus *Limnæa* (fig. 435) includes the so-called "Pond-snails," characterised by their thin, spiral, elongated shells, with a large body-whorl and an obliquely-twisted columella. The species of this genus commence in

the Wealden (Lower Cretaceous)—perhaps in the Upper Oolites — and are abundantly represented throughout the Tertiary series.

In the genus *Physa* (fig. 436) the shell is left-handed ("sinistral"), ovate, thin, and polished, with the aperture rounded in front. Species of this genus have been indicated as occurring in the Purbeck beds (Upper Oolites) and Wealden (Cretaceous). Most of the fossil species, however, belong to the Tertiary period, and the genus attains its maximum at the present day.

The genus *Ancylus* (fig. 437, C) comprises the so-called "River-limpets," at once distinguished by their thin, conical, limpet-shaped shells. A few fossil species are known, chiefly, if not exclusively, confined to the Tertiary period. The *Valenciennesia*, of the Tertiary, resembles a gigantic *Ancylus*, but the apex is much incurved, and an internal sulcus and corresponding superficial fold extend from the apex to the right margin, and exist in a less developed form on the left side.

Fig. 436.—*Physa columnaris*. Eocene.

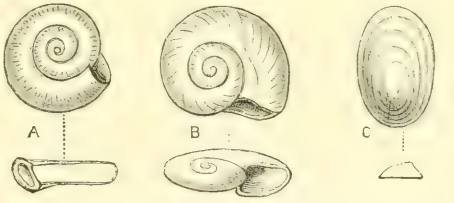


Fig. 437.—A, *Planorbis complanatus*, viewed from below and in front—Pliocene and Recent; B, *Planorbis discus*—Eocene—viewed from above and in front, reduced one-half; C, *Ancylus Matheroni*—Tertiary—viewed sideways and from above, the latter figure enlarged.

The genus *Planorbis* (fig. 437, A and B) comprises a number of well-known fresh-water shells, in which the shell is discoidal and many-whorled, the aperture crescentic, and the lip thin. The fossil species of this genus date from the Lias (?), but are not plentiful except in the Tertiary deposits, whence a large number of forms has been obtained.

FAM. 4. AURICULIDÆ.—Shell spiral, with a horny epidermis; aperture elongated and denticulated. The species of this family inhabit salt-marshes and places overflowed by

the sea. They are of little importance as fossils, dating from the Eocene Tertiary.

Order V. Operculata.—*Shell furnished with an operculum.*

Fam. 5. Cyclostomidæ.—Shell spiral, rarely elongated, often depressed. Aperture nearly circular. Operculum spiral. The genus *Cyclostoma* (fig. 438) includes almost all the fossil species of this family, and dates from the Eocene Tertiary. All the members of this family are terrestrial in their habits, and they are of small importance as fossils.

Fig. 438. — *Cyclostoma Arnoudii.* Eocene Tertiary.

Fam. 6. Aciculidæ.—Shell elongated, cylindrical; operculum thin and subspiral. A species of *Acicula* has been indicated as occurring in the Pliocene Tertiary; but the family is otherwise unrepresented by fossil forms.

CHAPTER XXVI.

PTEROPODA.

Class III. Pteropoda.—*The Pteropoda* are defined by being *free and pelagic, swimming by means of two wing-like appendages (epipodia), developed from each side of the anterior extremity of the body. The flexure of the intestine is neural.*

As to the position of the *Pteropoda* in the Molluscan scale, they must be looked upon as inferior in organisation to any of the *Gasteropoda,* of which class they are often regarded as the lowest division. They permanently represent, in fact, the transient larval stage of the Sea-snails.

The living Pteropods are all of small size, and are found swimming at the surface of the open ocean, often in enormous numbers. Locomotion is effected by two wing-like fins (figs. 439, 440) developed from the sides of the head.

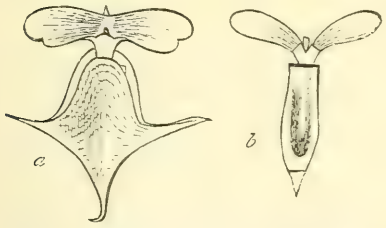


Fig. 439.—Pteropoda. *a*, *Cleodora pyramidata*; *b*, *Cuvieria columnella*. (After Woodward.)

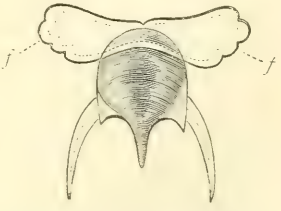


Fig. 440.—*Hyalea tridentata*, showing the shell and the lateral fins attached to the sides of the head (*f*, *f*).

In some cases the body is naked and unprotected; but there is commonly a symmetrical glassy shell, either con-

sisting of a dorsal and ventral plate united, or forming a spiral.

The *Pteropoda* are divided into two orders, termed *Thecosomata* and *Gymnosomata;* the former characterised by possessing an external shell and an indistinct head; the latter by being devoid of a shell, and by having a distinct head, with fins attached to the neck.

The Gymnosomatous Pteropods, in which there is no shell, as a matter of course, are wholly unknown in the fossil condition. The Thecosomatous Pteropods, in which there is a shell, are divided into two families—the *Hyaleidæ* and *Limacinidæ*. The latter comprises forms in which there is a small spiral shell, which is sometimes provided with an operculum; but it is unrepresented in a fossil state. The former family comprises forms in which the shell is symmetrical, straight or curved, globular or needle-shaped, and it is represented by a considerable number of fossil forms, most of which are extremely unlike any known living examples of the class, being often of comparatively colossal dimensions. The fossil forms mostly belong to the genera *Hyalea, Cuvieria, Cleodora, Hyolithes* (*Theca*), *Pterotheca, Tentaculites,* and *Conularia;* but other less important types are known to have existed in past time. Of the above-mentioned generic forms, the first three are well represented at the present day by living forms. The remaining four are almost exclusively Palæozoic, *Conularia* alone surviving into the earlier portion of the Mesozoic period. Not only is this the case, but the forms in question all commence their existence in the Lower Silurian or Upper Cambrian, and only *Hyolithes* and *Conularia* transgress the upper limit of the Devonian rocks. Lastly, almost all these forms are of comparatively gigantic size, and they differ in many respects from living forms.

Among the fossil members of the class, the largest genera are *Tentaculites, Hyolithes* (*Theca*), *Conularia,* and *Pterotheca.* These are also the most widely distributed types, and the ones with the longest vertical range. Taken as a whole, the Pteropods attain their maximum as fossils in the Lower Silurian rocks: they diminish gradually in number towards

the close of the Palæozoic period; they are hardly represented at all in the Mesozoic period; and they are present in the Tertiary period under well-known existing types.

In the genus *Hyalea* (fig. 441) the shell is globular, translucent, the dorsal plate extended into a hood; the aperture is contracted, with a lateral slit on each side. The fossil species are only known in the Miocene and Pliocene Tertiary, and the genus attains its maximum in existing seas. *Cleodora* has a pyramidal shell, and dates from the Miocene; and *Cuvieria* (fig. 439) has a cylindrical shell, and dates from the Pliocene. Both these genera attain their maximum at the present day. *Styliola* (fig. 442, C) is very closely related to *Cleodora*, and is also represented by both living and Tertiary forms, while a Silurian fossil has been referred to this genus.

Fig. 441.—*Hyalea Orbignyana.* Miocene Tertiary.

The Lower Palæozoic rocks contain numerous forms of the genus *Hyolithes*, this name seeming to have priority over the

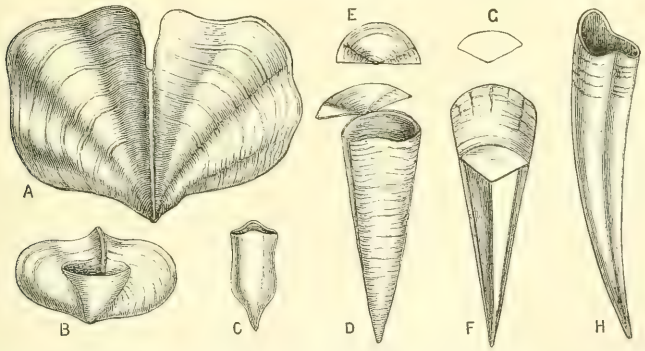


Fig. 442.—A, *Pterotheca corrugata*—Lower Silurian (after Salter); B, *Pterotheca transversa*—Silurian (after Salter); C, *Styliola* (*Clio*) *depressa*—Miocene; D, *Hyolithes* (*Theca*) *operculatus*; and E, its operculum—Upper Cambrian (after Salter); F, *Hyolithes aratus*—Upper Cambrian; and G, Cross-section of the same (after Salter); H, *Hyolithes acutus*—Silurian (after Eichwald).

more familiar *Theca*, as also over *Pugiunculus*. The shells included under the genus *Hyolithes* (fig. 442, D, F, H) are bayonet-shaped or conical, usually straight, but sometimes curved, of

thin texture, transversely striated or smooth, sometimes with marginal ribs, but without lateral appendages. The mouth of the shell is trigonal, and in some forms, at any rate, is furnished with an operculum (fig. 442, E), or occasionally furnished with curved lateral appendages. The length of the shell varies, but is commonly from an inch to an inch and a half. The genus is apparently allied to the recent *Clio*, but the dimensions of the shell much exceed those of any known species of the latter. Barrande enumerates eighty-four Palæozoic species, principally distributed in the Upper Cambrian and Silurian, but occurring also in the Devonian and Permian. *Pterotheca* (fig. 442, A and B), of the Silurian, in many respects resembles *Hyolithes;* but the median dagger-shaped shell is bordered by lateral concentrically-striated expansions or alations, thus coming to superficially resemble the carapace of certain of the Phyllopods.

The Silurian genus *Coleoprion* has a cylindrical and conical shell, the exterior of which is marked with chevron-shaped striæ. Possibly allied to the preceding types, but of very uncertain affinities, are the genera *Hemiceras* and *Salterella*. In the first of these are conical elongated shells, of circular section, in which the walls are thickened by the deposition of concentric calcareous lamellæ, till only a small tubular space is left in the centre. The genus is Silurian. *Salterella*, of the Upper Cambrian, comprises conical tubes, resembling the preceding in shape, but consisting of several hollow cones placed one within the other.

The genus *Conularia* is one of the most extraordinary of the extinct genera of the Pteropods, if only for the enormous size attained by many examples. The shape of the shell is very like that of some living Pteropods, but specimens occasionally reach the length of nearly a foot, with a breadth of more than an inch. The shell in *Conularia* (fig. 443) is straight, tapering towards one end, and having a sub-quadrate or rhomboidal aperture at the other. The form of the shell is generally distinctly four-sided, the sides being finely striated with transverse lines. The shell is generally of extreme tenuity; but the internal cavity is sometimes restricted by concentric lamellæ, and the apex may be partitioned off.

M. Barrande enumerates eighty-three species of *Conularia*, most of which are Palæozoic, commencing in the lowest Silurian deposits. The genus, however, extends into the Mesozoic rocks, the last species, so far as at present known, appearing in the Lias.

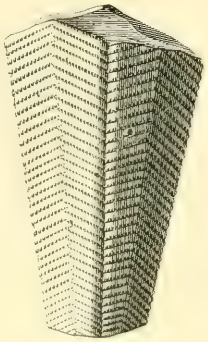


Fig. 443.—*Conularia ornata.* Devonian.

Lastly, the genus *Tentaculites* comprises a number of singular Palæozoic fossils, the true position of which cannot be said to be absolutely free from doubt. Most authorities now place *Tentaculites*, with apparently good reason, in the *Pteropoda;* but others would still refer this genus to the Tubicolar Annelides. It must be admitted, also, that in some respects *Tentaculites* approximates pretty closely to the Annelidous genera *Conchicolites* and *Cornulites.* Upon the whole, however, the mode of occurrence of *Tentaculites*, and its undoubted free habit of existence, leave little doubt as to its true place being amongst the Pteropods. The shell of *Tentaculites* (fig. 444) has the form of a straight conical tube, tapering towards one extremity to a pointed closed apex, and expanding towards the other to a circular aperture. The walls of the shell are thin, and are surrounded with numerous thickened rings or annulations, sometimes with intermediate striæ, over a whole or part of the length of the tube. The size of *Tentaculites* varies much in different cases, being sometimes less than a couple of lines in length, and sometimes attaining a length of an inch or more. Fifty-two species of *Tentaculites* are enumerated by M. Barrande, commencing in the Lower Silurian and ranging into the Devonian. The genus is, however, principally Silurian, and examples of some species often occur in myriads through a considerable thickness of strata.

Fig. 444.—*Tentaculites ornatus.* Upper Silurian. Europe and North America.

The typical species of *Tentaculites* possess an annulated

shell, but there is one curious little form (the *T. fissurella* of the Devonian), which, if rightly referred to this genus at all, has the peculiarity that the shell is destitute of the characteristic rings. This species is further remarkable as occasionally occurring in such extraordinary profusion as to actually form beds of limestone; as observed by the author and by Mr George Hinde in a thin limestone in the Devonian (Genesee Slates) of North America.

CHAPTER XXVII.

CLASS CEPHALOPODA.

Class IV. Cephalopoda.—The members of the *Cephalopoda* are defined by the possession of *eight or more arms placed in a circle round the mouth; the body is enclosed in a muscular mantle-sac, and there are two or four plume-like gills within the mantle. There is an anterior tubular orifice (the "infundibulum" or "funnel"), through which the effete water of respiration is expelled.*

The *Cephalopoda*, comprising the Cuttle-fishes, Squids, Pearly Nautilus, &c., constitute the most highly organised of the classes of the *Mollusca*. They are all marine and carnivorous, and are possessed of considerable locomotive powers. At the bottom of the sea they can walk about, head downwards, by means of the arms which surround the mouth, and which are usually provided with numerous suckers or "acetabula." They are also enabled to swim, partly by means of lateral expansions of the integument or fins (not always present), and partly by means of the forcible expulsion of water through the tubular "funnel," the reaction of which causes the animal to move in the opposite direction.

The majority of the living Cephalopods are naked, possessing only an internal skeleton, and this often a rudimentary one; but the Argonaut (Paper Nautilus) and the Pearly Nautilus are protected with an external shell, though the nature of this is extremely different in the two forms.

The body in the *Cephalopoda* is symmetrical, and is enclosed in an integument which may be regarded as a modi-

fication of the mantle of the other *Mollusca*. Ordinarily there is a tolerably distinct separation of the body (fig. 445) into an anterior cephalic portion (*prosoma*), and a posterior portion, enveloped in the mantle, and containing the viscera (*metasoma*). The head is very distinct, bearing a pair of large globular eyes, and having the mouth in its centre. The mouth is surrounded by a circle of eight, ten, or more, long muscular processes or "arms" (fig. 445), which are generally provided with rows of suckers. In the Octopod Cuttle-fishes there are only eight arms, and these are all nearly alike. In the Decapod Cuttle-fishes there are ten arms, but two of these — called "tentacles" — are much longer than the others, and bear suckers only at their extremities, which are enlarged and club-shaped. In the Pearly Nautilus the arms are numerous, and are devoid of suckers.

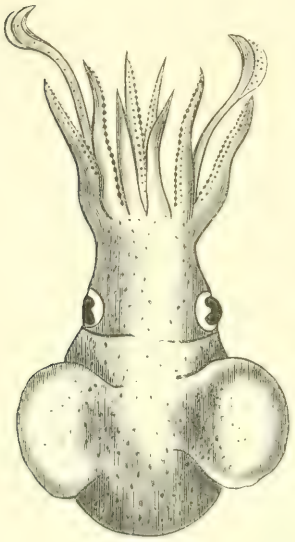


Fig. 445. — Cephalopoda. *Sepiola Atlantica*, one of the Cuttle-fishes. (After Woodward.)

The parts of the *Cephalopoda* which may be preserved in a fossil condition, and which thus interest the palæontologist, are the *mandibles*, the *ink-bag*, and the *skeleton*, whether this be internal or external.

The *mandibles* are contained within the mouth or "buccal cavity" of the animal, and have the form of powerful jaws, working vertically like the beak of a bird. They are horny or sub-calcareous, and in shape closely resemble the beak of a parrot, with this difference, that the largest of the two mandibles is placed inferiorly. Mandibles of this nature are present in both the Cuttle-fishes and the Pearly Nautilus, being horny in the former and calcareous in the latter, and they doubtless existed in all the extinct forms. The calcareous beaks not uncommonly occur as fossils, but they do not appear to have been observed out of the Juras-

sic and Cretaceous rocks. They are commonly called "Rhyncholites," and genera such as *Rhynchoteuthis* have been founded upon them (fig. 446).

The *ink-bag* is a special gland possessed by the Cuttle-fishes, for the purpose of secreting an inky fluid, which the animal can discharge into the water, so as to enable it to escape when menaced or pursued. The secretion of the ink-bag consists of finely-divided particles of carbon suspended in fluid, and it is extremely indestructible. The ink-bag, with its contained secretion, is not uncommonly found in the fossil condition; but it has only been observed in strata of Secondary age. In the Tetrabranchiate Cephalopods, in which there is an external shell, and this means of defence is not needed, there is no ink-bag.

The *shell* of the *Cephalopoda* is sometimes external, sometimes internal. The internal skeleton is known as the

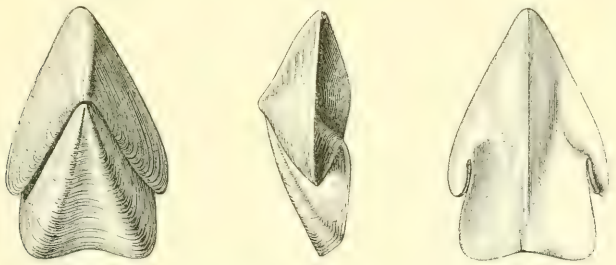


Fig. 446.—*Rhynchoteuthis Astieriana*. Lower Greensand (Cretaceous).

"cuttle-bone," "sepiostaire," or "pen" (*gladius*), and may be either corneous or calcareous (fig. 447, *a* and *b*). In some cases it is rendered complex by the addition of a chambered portion or "phragmacone," which is to be regarded as a visceral skeleton or "splanchnoskeleton." In *Spirula* the phragmacone (fig. 447, *c* and *d*) is the sole internal skeleton, and is coiled into a spiral, the coils of which lie in one plane, and are near one another, but not in contact. It thus resembles the shell of the Pearly Nautilus, but it is *internal*, and differs, therefore, entirely from the *external* shell of the latter. The only living Cephalopods which are provided with an external shell are the Paper Nautilus

(*Argonauta*) and the Pearly Nautilus (*Nautilus pompilius*); but not only is the structure of the animal different in each of these, but the nature of the shell itself is entirely different. The shell of the Argonaut is involuted, but is not divided

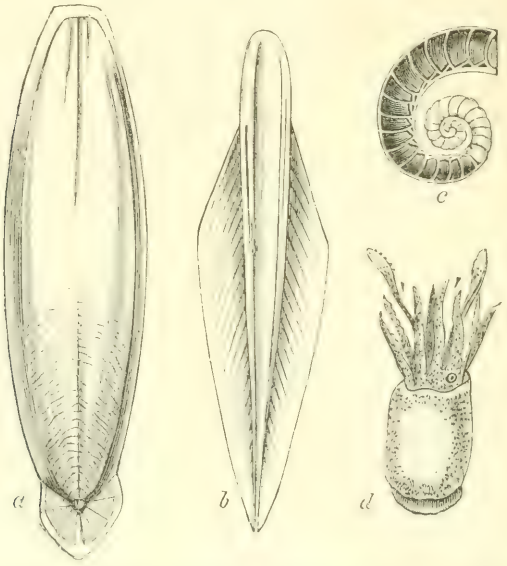


Fig. 447.—*a*, Internal skeleton of *Sepia ornata*; *b*, Pen of *Histioteuthis Bonelliana*; *c*, Shell ("phragmacone") of *Spirula fragilis*; *d*, Animal of *Spirula Peronii*.

into chambers, and it is secreted by the webbed extremities of two of the dorsal arms of the female. The arms are bent backwards, so as to allow the animal to live in the shell, but there is in reality no organic connection between the shell and the body of the animal. In fact, the shell of the Argonaut, being confined to the female, and serving by its empty apex as a receptacle for the ova, may be looked upon as a "nidamental shell," or, as it is secreted by a modified portion of the foot, it may more properly be regarded as a "pedal shell." The shell of the Pearly Nautilus (fig. 448), on the other hand, is a true pallial shell, and is secreted by the body of the animal, to which it is organically connected. It is involuted, but it differs from the shell of the Argonaut in being divided into a series of chambers by shelly partitions or septa, which are pierced by a

tube or "siphuncle," the animal itself living in the last chamber only of the shell.

The *Cephalopoda* are divided into two extremely distinct and well-marked orders, termed the *Dibranchiata* and *Tetrabranchiata*. The former is characterised by the possession of two gills only, and by the fact that the shell, if external (as it very rarely is), is never chambered. In this order are comprised the living Cuttle-fishes, Squids, and Paper Nautilus, with the extinct family of the *Belemnitidæ*. The latter is distinguished by the presence of four gills, and by the possession of an external many-chambered shell. This order is abundantly represented in past time, but has no other living representative than the Pearly Nautilus alone. The following table gives the characters and leading genera of the families of *Cephalopoda*:—

Synopsis of the Families of the Cephalopoda.

Class Cephalopoda.

Order I. Dibranchiata.

Animal with two branchiæ; not more than eight or ten arms, provided with suckers; an ink-bag. Shell commonly internal and rudimentary; rarely external, but not chambered.

Section A. Octopoda.

Arms eight, suckers sessile.

Fam. 1. *Argonautidæ.*

Female provided with a calcareous, external, monothalamous shell, secreted by the webbed extremities of two of the dorsal arms. Gen. *Argonauta.*

Fam. 2. *Octopodidæ.*

Shell internal, rudimentary, uncalcified. No pallial fins in most. Ill. Gen. *Octopus, Tremoctopus, Eledone, Pinnoctopus.*

Section B. Decapoda.

Arms eight, with two clavate "tentacles;" suckers pedunculated.

Fam. 3. *Teuthidæ.*

Shell an internal horny "pen" or "gladius." Fins mostly terminal. Ill. Gen. *Loligo, Onychoteuthis, Ommastrephes.*

Fam. 4. *Belemnitidæ.*

Shell internal, composed of a conical chambered portion ("phragmacone") with a marginal siphuncle, produced into a horny plate or "pen," and lodged in a cylindrical fibrous "guard." Ill. Gen. *Belemnites, Belemnitella, Belemnoteuthis.*

Fam. 5. *Sepiadæ.*

Shell calcareous, consisting of a broad, laminar plate, terminating in an imperfectly-chambered apex ("phragmacone"). Ill. Gen. *Sepia, Beloptera, Spirulirostra.*

Fam. 6. *Spirulidæ.*

Shell internal, nacreous, chambered, discoidal; the whorls separate; a ventral siphuncle. Gen. *Spirula.*

Order II. Tetrabranchiata.

Animal with four gills; arms more than ten, without suckers; no ink-bag; shell external, chambered, and siphuncled.

Fam. 1. *Nautilidæ.*

Sutures of the shell simple; the siphuncle central, subcentral, or near the concavity of the curved shells, simple.

Sub-family Nautilidæ proper.

Body-chamber capacious; aperture simple; siphuncle central or internal. Ill. Gen. *Nautilus, Lituites, Trochoceras.*

Sub-family Orthoceratidæ.

Shell straight, curved, or discoidal; body-chamber small; aperture contracted; siphuncle complicated. Ill. Gen. *Orthoceras, Phragmoceras, Cyrtoceras.*

Fam. 2. *Ammonitidæ.*

Shell discoidal, curved, spiral, or straight; body-chamber elongated; aperture guarded by processes, or closed by an operculum; sutures angulated, lobed, or foliaceous; siphuncle external or dorsal (on the convex side of the curved shells). Ill. Gen. *Ammonites, Ceratites, Baculites, Turrilites, Scaphites, Ancyloceras.*

As regards their general distribution in time, the Cephalopods are largely represented in all the primary groups of stratified rocks from the Lower Silurian up to the present day. Of the two orders of *Cephalopoda*, the *Tetrabranchiata* is the oldest, attaining its maximum in the Palæozoic period, decreasing in the Mesozoic and Kainozoic epochs, and being represented at the present day by the single genus *Nautilus*. Of the sections of this order, the *Nautilidæ* proper and the *Orthoceratidæ* are pre-eminently Palæozoic, and the *Ammonitidæ* are not only pre-eminently but are almost exclusively Secondary. Of the abundance of the two former families in the Silurian seas some idea may be obtained when it is mentioned that over a thousand species have been described by

M. Barrande from the Silurian basin of Bohemia alone. The *Nautilidæ* proper have gradually decreased in numbers from the Palæozoic, through the Secondary and Tertiary periods, to the present day. The *Orthoceratidæ* died out much sooner, being exclusively Palæozoic, with the exception of the genera *Orthoceras* itself and *Cyrtoceras*, which survived into the commencement of the Secondary period, finally dying out in the Trias.

The second family of the *Tetrabranchiata*—viz., the *Ammonitidæ*—is almost exclusively Secondary, being very largely represented by numerous species of the genera *Ammonites*, *Ceratites*, *Baculites*, *Turrilites*, &c. The chief Palæozoic genera are *Goniatites* and *Bactrites*, of which the former is found from the Upper Silurian to the Trias, whilst the latter is a Silurian and Devonian form. The genus *Ammonites*, however, occurs in the Carboniferous, and has been also found in strata of Tertiary age. The genus *Ceratites* is characteristically Triassic, but it is said to occur in the Devonian rocks, and some species are Cretaceous. All the remaining genera are exclusively Secondary, the genera *Baculites*, *Turrilites*, *Hamites*, and *Ptychoceras* being confined to the Cretaceous period.

Of the Dibranchiate Cephalopods the record is less perfect, as they have few structures which are capable of preservation. They attain their maximum, as fossils, shortly after their first appearance in the Secondary rocks, where they are represented by the large and important family of the *Belemnitidæ*. Some of the *Teuthidæ* and *Sepiadæ* are found both in the Secondary and in the Tertiary rocks, and two species of Argonaut have been discovered in the later Tertiaries. No example of a Dibranchiate Cephalopod is known from the Palæozoic deposits, and the order attains its maximum at the present day.

Tetrabranchiate Cephalopods.

The Tetrabranchiate Cephalopods are characterised by being *creeping animals, protected by an external, many-chambered shell, the septa between the chambers of which are perforated by a mem-*

branous or calcareous tube, termed the "siphuncle." The arms are numerous, and are devoid of suckers; the branchiæ are four in number, two on each side of the body; the funnel does not form a complete tube; and there is no ink-bag.

The Tetrabranchiate Cephalopods have an enormous development in past time, an immense number of species, mostly belonging to extinct types, being known from the Palæozoic rocks alone. In the Mesozoic rocks the members of this order were almost equally abundant. In the Tertiary rocks the order is reduced to the single genus *Nautilus*, represented at the present day by the single species *Nautilus pompilius* (the Pearly Nautilus), with some very nearly allied forms. The palæontological importance of this order being so great, it may be as well to preface the account of the extinct forms by a short description of the structure of the living *Nautilus pompilius*, as described by Professor Owen, from the most perfect specimen which has as yet been obtained.

The soft structures in the Pearly Nautilus may be divided into a posterior, soft, membranous mass (*metasoma*), containing the viscera, and an anterior muscular division, comprising the head (*prosoma*); the whole being contained in the outermost, capacious chamber (the body-chamber) of the shell, from which the head can be protruded at will. The shell itself (fig. 448) is involuted and many-chambered, the animal being contained successively in each chamber, and retiring from it as its size becomes sufficiently great to necessitate the acquisition of more room. Each chamber, as the animal retires from it, is walled off by a curved, nacreous septum; the communication between the chambers being still kept up by a membranous tube or siphuncle, which opens at one extremity into the pericardium, and is continued through the entire length of the shell. The position of the siphuncle is in the centre of each septum.

Posteriorly the mantle of the Nautilus is very thin, but it is much thicker in front, and forms a thick fold or collar surrounding the head and its appendages. From the sides of the head spring a great number of muscular prehensile processes or "arms," which are annulated, but are not provided with cups or suckers. In the centre of the head is the

mouth, surrounded by a circular fleshy lip, external to which is a series of labial processes. The mouth opens into a buccal cavity, armed with two horny mandibles, partially calcified towards their extremities, and shaped like the beak

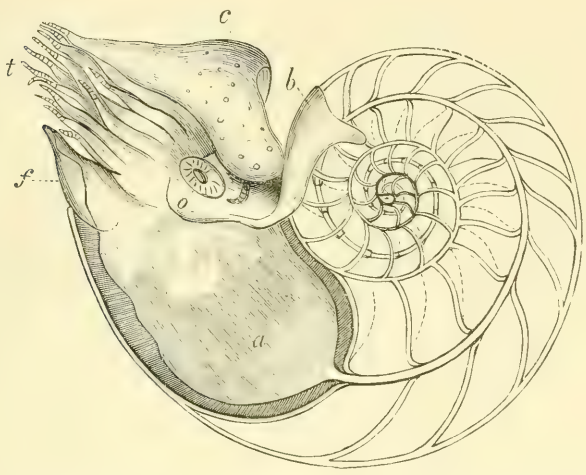


Fig. 448.—Pearly Nautilus (*Nautilus pompilius*). *a*, Mantle; *b*, Its dorsal fold; *c*, Hood; *o*, Eye; *t*, Tentacles; *f*, Funnel.

of a parrot, except that the under mandible is the longest. There is also a "tongue," which is fleshy and sentient in front, but is armed with recurved teeth behind. The gullet opens into a large crop, which in turn conducts to a gizzard, and the intestine terminates at the base of the funnel. On each side of the crop is a well-developed liver.

The heart is contained in a large cavity, divided into several chambers, and termed the "pericardium" (Owen). The respiratory organs are in the form of four pyramidal branchiæ, two on each side.

The chief masses of the nervous system are the cerebral and infra-œsophageal ganglia, which are partially protected by a cartilaginous plate, which is to be regarded as a rudimentary cranium, and which sends out processes for the attachment of muscles. The organs of sense are two large eyes, attached by short stalks to the sides of the head, and

two hollow plicated sub-ocular processes, believed to be olfactory in their function.

The reproductive organs of the female consist of an ovary, oviduct, and accessory nidamental gland.

There is no ink-bag, and the funnel does not form a complete tube, but consists of two muscular lobes, which are simply in apposition. It is the organ by which swimming is effected, the animal being propelled through the water by means of the reaction produced by the successive jets emitted from the funnel. The function of the chambers of the shell appears to be that of reducing the specific gravity of the animal to near that of the surrounding water, since they are probably filled with some gas secreted by the animal. The function of the siphuncle is unknown, except in so far as it doubtless serves to maintain the vitality of the shell.

Shell of the Tetrabranchiata.—The shells of all the *Tetrabranchiata* agree in the following points:—

1. The shell is external.

2. The shell is divided into a series of chambers by plates or "septa," the edges of which, where they appear on the surface, are termed the "sutures."

3. The outermost chamber of the shell is the largest, and is the one inhabited by the animal.

4. The various chambers of the shell are traversed by a tube, termed the "siphuncle."

Agreeing in all these fundamental points of structure, two very distinct types of shell may be distinguished as characteristic of the two families *Nautilidæ* and *Ammonitidæ*, into which the order *Tetrabranchiata* is divided.

In the family *Nautilidæ* (fig. 449), the "septa" of the shell are simple, curved, or slightly lobed; the "sutures" are more or less completely plain; and the "siphuncle" is central, sub-central, or internal (*i.e.*, on the *concave* side of the curved shells).

In the family *Ammonitidæ* (fig. 449), on the other hand, the septa are folded and complex; the sutures are angulated, zigzag, lobed, or foliaceous; and the siphuncle is external (*i.e.*, on the *convex* side of the curved shells).

In both these great *types* of shell, a series of representative

forms exists, resembling each other in the manner in which the shell is folded or coiled, but differing in their fundamental structure. All these different forms may be looked upon as produced by the modification of a greatly-elongated

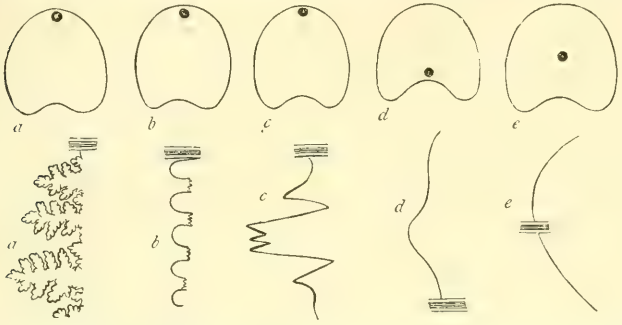


Fig. 449.—Diagram to illustrate the position of the siphuncle and the form of the septa in various Tetrabranchiate Cephalopoda. The upper row of figures represents transverse sections of the shells, the lower row represents the edges of the septa. *a, a, Ammonite* or *Baculite; b, b, Ceratite; c, c, Goniatite; d, d, Clymenia; e, e, Nautilus* or *Orthoceras.*

cone, the structure of which may be in conformity with the type either of the *Nautilidæ* or of the *Ammonitidæ.* The following table (after Woodward) exhibits some of the representative forms in the two families :—

	Nautilidæ.	*Ammonitidæ.*
Shell straight, ...	Orthoceras, .	Baculites.
„ bent on itself, . .	Ascoceras, .	Ptychoceras.
„ curved, ...	Cyrtoceras, .	Toxoceras.
„ spiral, ...	Trochoceras, .	Turrilites.
„ discoidal, ...	Gyroceras, . .	Crioceras.
„ discoidal and produced,	Lituites, . .	Ancyloceras.
„ involute, ...	Nautilus, . .	Ammonites.

Distribution of Tetrabranchiata in Time.—Regarded as a whole, the Tetrabranchiate Cephalopods form a group which early attained its maximum, and which is now almost extinct. The greatest development, in point of numbers, took place in the Palæozoic period; and the forms then existing belonged to decidedly simpler types than those which followed them. The greatest number of *types* existed during the Mesozoic period; and here the order still maintained

a great abundance of individuals. With the close of the Secondary epoch a large number of complex types disappeared wholly, and the order was left without any representative in the Tertiary rocks except the simple and ancient genus *Nautilus*.

As regards the two great sections of the order, the *Nautilidæ* are the most ancient, dating their existence from the Lower Silurian, if not from the Upper Cambrian. Not only is this the case, but they are pre-eminently Palæozoic, very few generic types surviving into the Secondary period, and only one into the Tertiary. The *Ammonitidæ*, on the other hand, are pre-eminently Mesozoic, and no member of this group is known with certainty to have survived into the Kainozoic period. This group, however, is represented by two comparatively simple types in the Palæozoic period, commencing their existence from the Silurian.

In the following are given the characters and distribution in time of the leading forms of the Tetrabranchiate Cephalopods :—

Nautilidæ.

Fam. I. Nautilidæ. — *Sutures of the shell simple; the siphuncle simple, central, sub-central, or near the concavity of the curved shells.*

Recent researches have also shown that the *development* of the shell of the *Nautilidæ* is effected in a manner very different to that which obtains among the *Ammonitidæ*. In all those forms of the *Nautilidæ* which have been examined in a sufficiently early condition, or in sufficiently perfect specimens, it appears that the embryonic shell or initial chamber has the form of a simple cone, not in any way inflated, and not separated from the later-formed portion of the shell by any constriction or distinct line of demarcation. The surface of the embryonic shell is usually marked by a network of transverse and longitudinal striæ, which mostly become obsolete in the adult shell. The extremity of the initial chamber may be pointed, but is more usually obtuse and rounded (fig. 450, A and C); and it also exhibits an oval, rounded, or slit-like scar or cicatrix, which marks the place

where there originally existed a small fissure. Opinions differ as to the function subserved by this primitive fissure; but M. Barrande thinks it possible that it transmitted a ligament by which the young shell was temporarily attached to some foreign body. The initial element of the siphuncle is a somewhat dilated cæcal tube, the commencement of which is attached to the front wall of the initial chamber, apparently without entering into its cavity. Munier-Chalmas, however, has pointed out that there exists in the interior of the initial chamber an organ ("prosiphon"), which seems to take the place of the siphuncle during early life.

In the family of the *Ammonitidæ*, on the other hand, the initial portion of the shell is an inflated spheroidal, oval, or pyriform body, which is termed the "ovisac" (fig. 450, D-G),

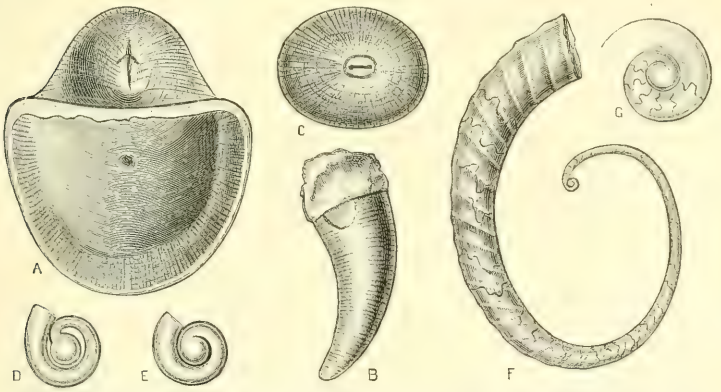


Fig. 450.—Development of Tetrabranchiate Cephalopods. A, The inner end of the shell of *Nautilus pompilius*, enlarged, showing the initial chamber and the cicatrix; B, *Cyrtoceras præposterum*—Silurian, showing the commencement of the shell; and (C) the initial chamber viewed from below, showing the cicatrix; D, Inner portion of the shell of *Goniatites bicanaliculatus*—Devonian, showing the inflated ovisac; E, First turn of the spire of *Goniatites sublamellosus*—Devonian; F, *Crioceras Studeri*—Cretaceous, enlarged, showing the ovisac; G, Ovisac and first turn of the spire of *Ammonites quadrisulcatus*—Cretaceous, enlarged. (After Barrande.)

and which is separated from the first turn of the shell by a distinct constriction. The ovisac communicates with the first air-chamber by a narrow elliptical transverse aperture. There is no structure in the ovisac which corresponds with the cicatrix of the initial chamber of the *Nautilidæ;* and the closed and dilated commencement of the siphuncle projects to some distance into the cavity of the ovisac. According to

the views of Barrande, the ovisac of the *Ammonitidæ* is a structure not represented at all in the embryonic shell of the *Nautilidæ*.

Sub-family 1. Nautilidæ Proper.—Body-chamber capacious; aperture of the shell simple; siphuncle central or internal. The chief genera of this sub-family are *Nautilus*, *Lituites*, *Trochoceras*, and *Clymenia*, of which the last three are exclusively Palæozoic, whilst the first ranges through all the great formations from the Silurian upwards, and is represented at the present day by the Pearly Nautilus.

In the genus *Nautilus* (fig. 451) the shell is involute or discoidal, consisting of a few whorls coiled into a flat spiral.

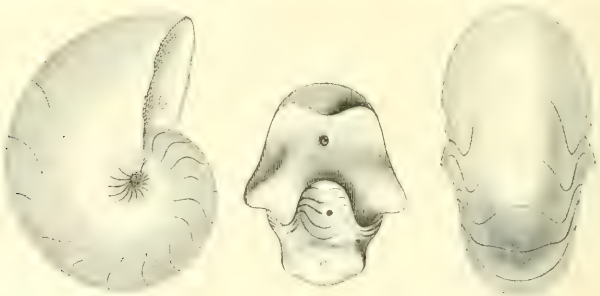


Fig. 451.—*Nautilus Danicus*. Upper Cretaceous ("Danien" of D'Orbigny).

The body-chamber is of large size, and the siphuncle is central, or nearly so. The genus *Nautilus* ranges from the Upper Silurian to the present day, having its maximum of development in the Carboniferous period. The Palæozoic forms (fig. 452) are mostly discoidal, having the whorls more or less completely exposed. The *Nautili* of later deposits are mostly like the living species in having each whorl overlapping the preceding, so that merely an "umbilicus" is visible. Many of the extinct forms, belonging to all ages, agree with the living Nautilus in having the surface quite smooth (*Lævigati*). Others, which are especially characteristic of the Jurassic rocks, have the surface striated (*Striati*). Others, chiefly of Cretaceous age, have the surface marked by distinct ribs (*Radiati*).

In the Upper Silurian and Devonian rocks *Nautili* are

few; in the Carboniferous, many species are known; in the Permian rocks and Trias are but few species; but the Jurassic and Cretaceous rocks have yielded a considerable

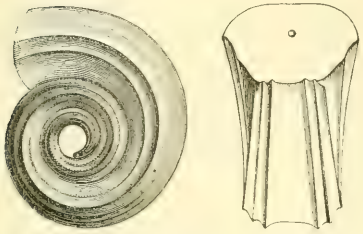


Fig. 452.—*Nautilus Koninckii.* Carboniferous.

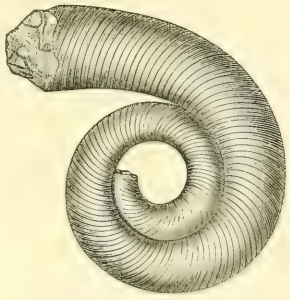


Fig. 453.—*Lituites cornu-arietis.* Lower Silurian.

number. Lastly, several Tertiary species are known, all of which agree with the living *Nautilus pompilius* in having their surface completely smooth.

In the genus *Lituites* (fig. 453) the shell is at first coiled discoidally, with close or disconnected whorls; but the last chamber is produced into a straight or slightly-curved line. The siphuncle is placed in the centre of the septa of the shell, and the mouth of the shell is contracted and keyhole-shaped. All the known species of *Lituites* are confined to the Silurian formation; but some occur in deposits the age of which is probably Upper Cambrian.

Ophidioceras, of the Silurian, resembles *Lituites,* but the terminal produced portion of the shell is short or wanting; while the *Discoceras* of the same formation, though resembling the preceding in shape, possesses a simple aperture.

The genus *Trochoceras* is one which was founded by M. Barrande to include certain singular Silurian Cephalopods in which the shell is doubly curved. In the typical forms—corresponding with *Turrilites* amongst the *Ammonitidæ*—the coils of the shell are in contact and pass obliquely round a central axis, so that the shell becomes turreted. In other cases, however, the shells are simply bent, and we have an approach to the genus *Cyrtoceras.*

In the genus *Clymenia* (fig. 454) the shell is discoidal,

coiled into a flat spiral, and closely resembling some of the older forms of *Nautilus*. The inner side of each whorl is deeply excavated for the reception of the convexity of the internal whorl. The septa are simple, like those of *Nautilus*, or are slightly lobed, and the siphuncle is *internal*, placed on the concave side of the whorls. Numerous species of *Clymenia* are known, all the typical forms belonging to the Devonian period; and some of the Upper Devonian limestones of Germany are so profusely charged with fossils of this genus as to have received the name of "Clymenienkalk."

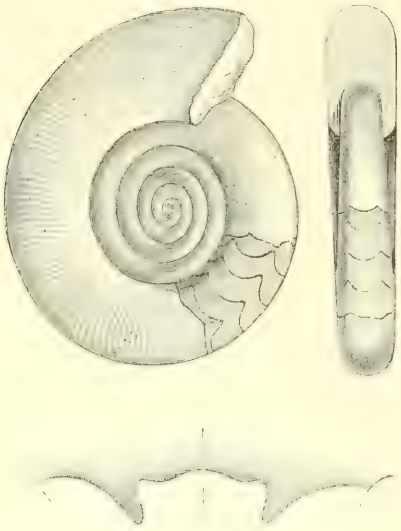


Fig. 454.—*Clymenia Sedgwickii*. Devonian. The lower figure shows the form of the suture.

From the general lobation of its septa, *Clymenia* is clearly to be approximated to *Goniatites*, with which the genus is sometimes placed. The forms with simple septa occur both in the Silurian and Devonian, and are probably best regarded as a distinct genus—namely, *Trocholites*. *Aturia*, again, of the Tertiary period, has thick walls and a large siphuncle, while the septa have a large lateral lobe. Lastly, *Gyroceras*, principally Devonian in its range, though also occurring in the Silurian, may be placed here. The shell is in the form of a flat spiral, but the volutions are not in contact, the siphuncle is placed on the convex side of the shell, and the septa are simple. This genus, therefore, resembles the *Ammonitidæ* in the position of the siphuncle, but agrees with the *Nautilidæ* in the possession of simple septa.

Sub-family 2. Orthoceratidæ.—Shell straight, curved or

discoidal; body-chamber small; aperture of the shell small, sometimes extremely contracted; siphuncle complicated. The *Orthoceratidæ* commence in the lowest Silurian deposits, and attain their maximum of development in the Silurian rocks. The family is well represented in the Devonian and Carboniferous rocks, but is much reduced in numbers in the Permians. The last appearance of the family is in the Triassic rocks, where it is represented by the genera *Orthoceras* and *Cyrtoceras*. The chief genera of this sub-family are *Orthoceras, Gomphoceras, Phragmoceras, Cyrtoceras,* and *Ascoceras.*

In the genus *Orthoceras* (fig. 455) the shell is straight, the

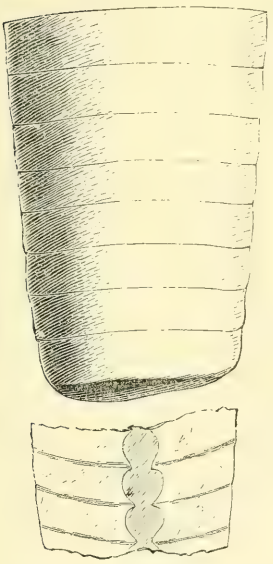


Fig. 455.—Fragment of *Orthoceras* (*Ormoceras*) *crebriseptum*—Cincinnati Group, North America, of the natural size. The lower figure is a section showing the air-chambers, and the form and position of the siphuncle. (After Billings.)

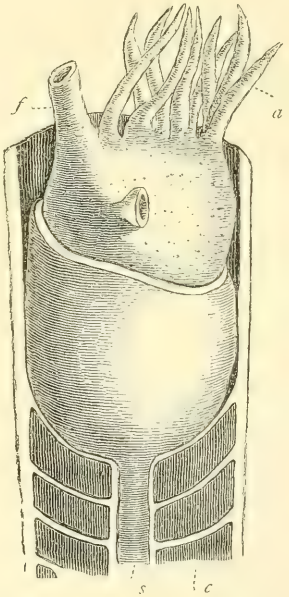


Fig. 456.—Restoration of *Orthoceras*, the shell being supposed to be divided vertically, and only its upper part being shown. *a*, Arms; *f*, Muscular tube ("funnel") by which water is expelled from the mantle-chamber; *c*, Air-chambers; *s*, Siphuncle.

siphuncle central or excentric, often of a very complex structure, and the aperture of the shell sometimes contracted. The *Orthocerata* are pre-eminently fossils of the Silurian,

Devonian, and Carboniferous rocks. They are, however, found in the Permians, and, passing into the Mesozoic series, they make their last appearance near the summit of the Triassic rocks. They sometimes attained an enormous size, occasionally exceeding six feet in length, with a diameter of more than a foot. Some idea of the vast numbers of these Cephalopods in the Palæozoic seas may be obtained from the statement that M. Barrande enumerates more than five hundred species as occurring in the small Silurian basin of Bohemia alone. The numerous species of *Orthoceras* are divided by the above-named distinguished palæontologist into two principal sections—the Short-coned Orthoceratites, and the Long-coned Orthoceratites—according as the shell has the form of a short cone with a large apical angle, or of a prolonged cone with a small apical angle. The first of these groups is a very small one, and almost all the more common forms come into the second group.

The nature of the siphuncle is very different in different *Orthocerata*, and more or less well-marked sub-genera have been founded upon the characters of this structure. In the sub-genus *Huronia* the siphuncle is of very large size, each joint being cylindrical below but inflated above, the outer walls of the siphuncle being connected with an internal central tube by radiating plates. In the forms termed *Cochleati* the siphuncle consists of a succession of spheroidal bead-like joints. In the sub-genus *Endoceras* the siphuncle is very large, marginal, excentric, or central, and it is partitioned off by funnel-shaped diaphragms. There is, however, considerable difference of opinion as to the true nature of the siphuncle in this sub-genus. In *Tretoceras* there is a nearly central siphuncle, but the uppermost septa are traversed by a deep lateral cavity, which communicates above with the body-chamber. The genus is Lower Silurian. Lastly, in the sub-genus *Gonioceras* the transverse section of the shell is flattened, and the sutures are undulated.

The genus *Cyrtoceras* (fig. 457) very closely resembles *Orthoceras*, but the shell is curved instead of being straight, and the siphuncle is either sub-central, or is more commonly *internal*—*i.e.*, on the concave side of the shell. *Cyrtoceras*

has about the same vertical range as *Orthoceras*, ranging from the Silurian through all the Palæozoic formations, and disappearing in the Trias. The genus is characteristically Silurian, and M. Barrande has described nearly two hundred and fifty species from rocks of this age in Bohemia.

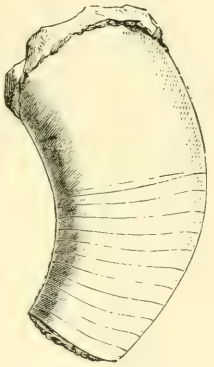


Fig. 457.—*Cyrtoceras isodorus*. (Billings.) Lower Silurian.

In the genus *Phragmoceras* (fig. 458) the shell is curved, and its aperture is contracted in the most extraordinary manner in the middle, so as to assume somewhat of the shape of a keyhole. The siphuncle in the majority of cases is placed upon the concave side of the shell. In other cases, the ventral side of the Mollusc corresponds with the convex side of the shell. The species of *Phragmoceras* are Silurian and Devonian, mainly the former; and M. Barrande enumerates thirty-eight species as occurring in the Silurian basin of Bohemia.

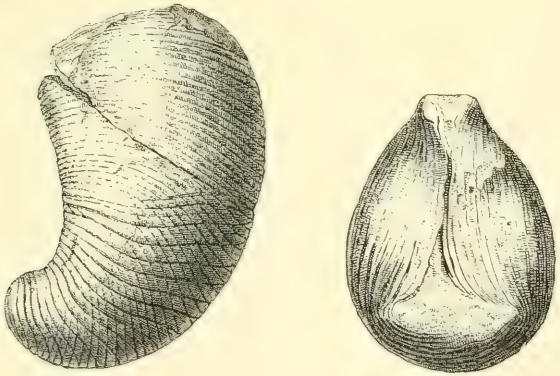


Fig. 458.—*Phragmoceras* (*Campulites*) *ventricosus*. Upper Silurian. The right-hand figure shows the form of the aperture.

In the genus *Gomphoceras* the shell (fig. 460, A and B) is spindle-shaped, or globular, tapering towards its apex. The aperture is contracted in the middle, like that of *Phragmoceras*, and the siphuncle is generally sub-central. In most

cases the ventral side of the shell is relatively the most convex, but the reverse of this sometimes occurs. The species of *Gomphoceras* range from the Silurian to the Carboniferous, but belong mainly to the former. M. Barrande enumerates no less than seventy-three species as occurring in the Silurian rocks of Bohemia.

The genus *Ascoceras* (fig. 459) comprises some singular forms in which the shell is globular or flask-shaped, and the septa do not run at right angles to the axis of the shell, but nearly parallel with it, being at the same time curved in an extraordinary manner, so that the body-chamber is prolonged downwards on one side almost to the bottom of the shell. The air-chambers also are restricted to a portion only of the shell. In *Aphragmites*, again, the air-chambers are not persistent. Both these genera are exclusively confined to the Silurian rocks, abounding chiefly in the upper division of the series.

Fig. 459. — *Ascoceras Canadensis* (Billings), showing the form of the septa. Lower Silurian.

Numerous other generic and sub-generic types are included under the *Orthoceratidæ*, of which the following deserve a passing mention. In the Silurian genus *Cyrtocerina* (fig. 460, c) the shell is curved, and has the general shape of *Cyrtoceras*, but it is much more broadly conical, and the siphuncle is of large size and placed on the dorsal side. *Nothoceras*, also Silurian, has a nautiloid shell, with simple septa, and likewise a dorsal siphuncle. *Bathmoceras*, from the same formation, has the siphuncle composed of a series of funnel-shaped tubes, which fit into one another, their narrow extremities being directed upwards. Lastly, *Aulacoceras* resembles *Orthoceras* in general form, but the shell is thick,

longitudinally-ridged, with two deep lateral furrows, and the siphuncle is marginal and situated on the dorsal side of the

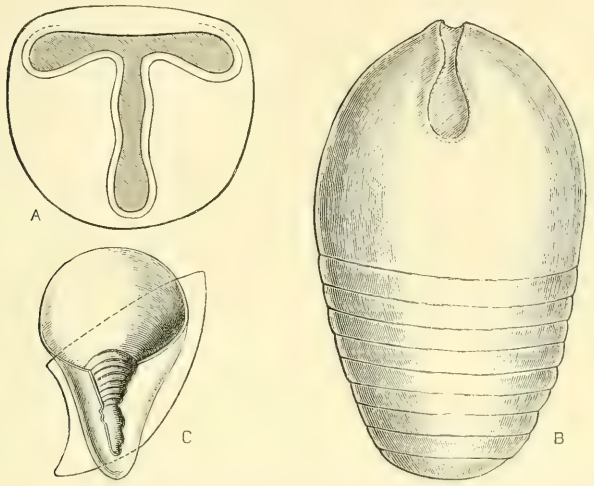


Fig. 460.—A, Aperture of the shell of *Gomphoceras Bohemicum*, reduced in size; B, Side view of a small specimen of the same—Silurian; C, *Cyrtocerina typica*—Lower Silurian (after Barrande and Billings).

shell. The genus is only known as occurring in the Triassic formation.

AMMONITIDÆ.

FAM. II. AMMONITIDÆ.—*Shell discoidal, curved, spiral, or straight; body-chamber elongated; sutures angulated, lobed, or foliaceous; siphuncle external or dorsal, on the convex side of the curved shells. Embryonic shell in the form of a spheroidal sac, separated from the first air-chamber by a distinct constriction.*

The chief point by which the *Ammonitidæ* are distinguished from the *Nautilidæ* is the nature of the septa between the air-chambers. The latter have septa which are simply curved, and which consequently exhibit plain or very slightly lobed edges or sutures. In the *Ammonitidæ*, on the other hand, the septa are "nearly flat in the middle, and folded round the edge (like a shirt-frill), where they abut against the outer shell-wall" (Woodward). The

result of this is that the "sutures" or edges of the septa appear on the surface of the shell in the form of angulated, lobed, or foliaceous lines (fig. 461).

The angulated or digitated portions of the suture which are directed inwards, away from the mouth of the shell, are called the "*lobes*." The elevations between the "lobes," which point towards the mouth of the shell, are called the "*saddles*." These parts have the following arrangement (fig. 461): In the middle of the back or convex surface of the shell, traversed by the siphuncle, is a single unpaired lobe which is termed the "dorsal lobe" (D). The lobe on each side of this is the "lateral-superior" lobe (L). The lobe next to this again is the "lateral-inferior" lobe (E); and the lobes which follow this (of a variable number) are the "auxiliary" lobes (A^1, A^2, A^3, A^4). Lastly, there is a second unpaired lobe immediately opposite to the dorsal lobe, placed upon the concave side of the shell, and termed the "ventral" lobe. The "saddles" are similarly sub-

Fig. 461.—One half of the suture of *Ammonites Truellii*. D, Dorsal lobe, traversed by the siphuncle; L, Lateral-superior lobe; E, Lateral-inferior lobe; A^1, A^2, A^3, A^4, Auxiliary lobes; SD, Dorsal saddle; SL, Lateral saddle; s^1, s^2, s^3, s^4, Auxiliary saddles.

divided. Between the dorsal and lateral-superior lobes comes the "dorsal saddle" (SD). Next to this, between the superior-lateral and inferior-lateral lobes, is placed the "lateral saddle" (SL) on each side; and this is followed by a variable number of "auxiliary saddles" (s^1, s^2, s^3, s^4).

The aperture of the shell in the *Ammonitidæ* is commonly furnished with lateral processes of greater or less length; and in some, if not in all cases, it was further pro-

tected by a horny or shelly operculum. Sometimes the operculum consists of a single piece: but in other cases it is divided into two symmetrical halves by a straight median suture. The opercula of this latter kind were originally described as separate fossils, under the name of *Trigonellites*.

As regards the general distribution in time of the *Ammonitidæ*, the earliest-known forms of the group appear in the Silurian rocks, the genus *Bactrites* in the Lower Silurian, and *Goniatites* in the Upper Silurian. No other Palæozoic types of the group are known, except a few recently discovered species of *Ammonites* in the Carboniferous rocks of India; but with the commencement of the Mesozoic period begins an era in which an enormous development of the *Ammonitidæ* took place. The genus *Ceratites* is characteristically Triassic. The Jurassic rocks are chiefly distinguished by species of the genus *Ammonites* itself, though other generic types are not wanting. Lastly, in the Cretaceous rocks we find, along with *Ammonites* proper, several remarkable forms, such as *Turrilites, Baculites, Hamites, Scaphites,* and *Ptychoceras.* With the close of the Cretaceous period the *Ammonitidæ* disappeared altogether, and no example of this large and varied family has as yet been detected in deposits of undoubted Tertiary date, or is known to exist in Recent seas. It should be added, however, that Ammonites occur in certain deposits in North America which are believed by some geologists to be of Lower Tertiary age.

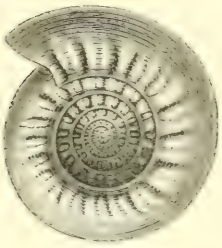
Genera of Ammonitidæ.

The genus *Goniatites* (fig. 462) comprises ancient forms of the *Ammonitidæ*, in which the shell is discoidal; the sutures are simply-lobed or angulated; and the siphuncle is dorsal. The earliest-known forms of this genus are found in the Upper Silurian rocks, the last in the Trias, and the most in the Carboniferous.

The genus *Bactrites* comprises forms quite similar to *Goniatites*, except that the shell, instead of being rolled up, is straight. The genus *represents Orthoceras*, from which it differs in the possession of lobed septa and in the position of

the siphuncle. The known species range from the Lower Silurian to the Devonian.

Goniatites and *Bactrites* are sometimes raised to the rank of a distinct sub-family (*Goniatitida*), and many palæontologists place *Clymenia* along with them. As regards its development, *Goniatites* is shown to belong to the *Ammonitidæ* by its possession of an inflated "ovisac" or embryonic shell (*see* fig. 450), but its simply-lobed septa separate it from the true *Ammonites*, of which it is an ancient and comparatively simple representative.



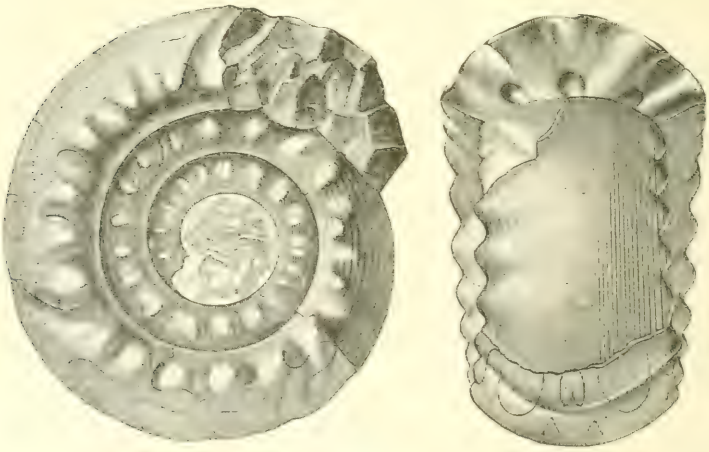


Fig. 462.—*Goniatites* (*Aganides*) *Josse*. Carboniferous.

The genus *Ceratites* (fig. 463) comprises forms which resemble *Goniatites* in having a discoidal shell, the coils of which lie in one plane and are contiguous. It is distinguished, however, from *Goniatites* on the one hand and *Ammonites* on the other, by having the "lobes" of the suture denticulated or crenulated, whilst the "saddles" are simply rounded. The species of *Ceratites* are typically Triassic, the best-known form being the *C. nodosus* of the Muschelkalk. Some species, however, occur in the Creta-

ceous rocks, though no member of the genus has as yet been detected in the intervening Jurassic deposits.

The comprehensive genus *Ammonites* comprises by far the greater number of the *Ammonitidæ*, several hundred species being already known. The shell in *Ammonites* is spirally rolled up into a flat spiral, all the volutions of which are contiguous (figs. 464-469). The innermost whorls of the shell are more or less concealed; the septa are undulated; the sutures are lobed, foliaceous, or ramified; and the siphuncle is dorsal. The species of the genus *Ammonites* range from the Trias to the Chalk, and are thus exclusively confined to the Secondary period. (It should

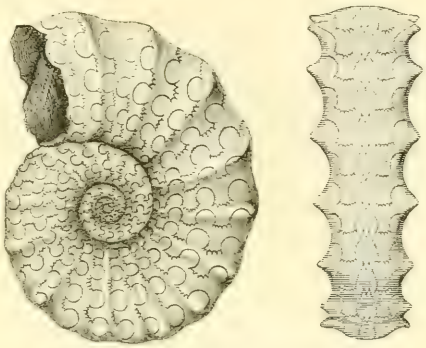


Fig. 463.—*Ceratites nodosus.* Muschelkalk (Middle Trias).

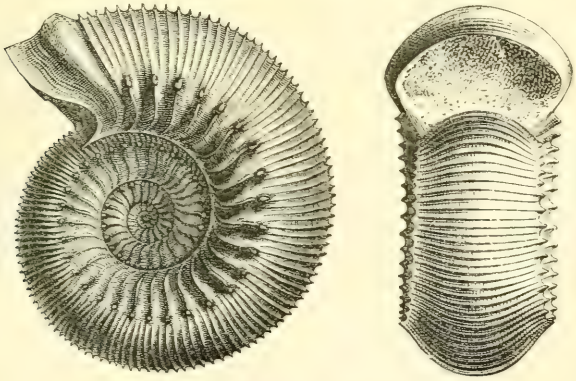


Fig. 464.—*Ammonites Humphresianus.* Inferior Oolite.

be remembered, however, as before said, that species of *Ammonites* are found in North America in beds which some believe to belong to the Eocene Tertiary.) Within these limits, each rock-group is characterised by partic-

ular species, the number of individuals being often very great, and the size which is sometimes attained being nothing short of gigantic. In the Jurassic rocks particular species of *Ammonites* are associated with particular groups

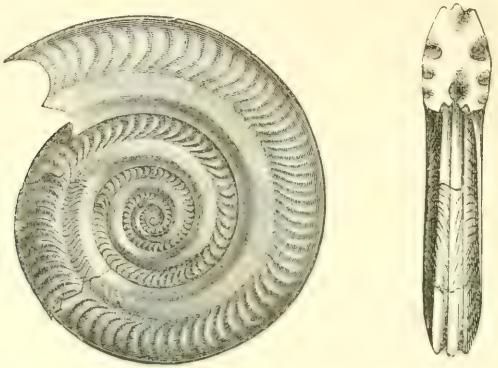


Fig. 465.—*Ammonites bifrons.* Lias.

of fossils at definite horizons; and it is thus possible to distinguish a certain number of zones, each especially characterised by a particular Ammonite. Some of these zones are very persistent and extend over very wide areas, thus affording valuable aid to the geologist in his determination of rocks. It is to be remembered, however, that there are

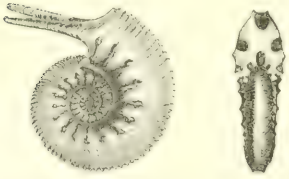


Fig. 466.—*Ammonites Jason.* Jurassic.

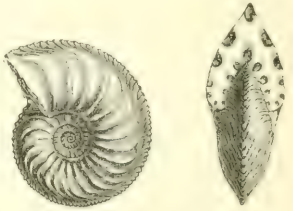


Fig. 467.—*Ammonites cordatus.* Jurassic.

other species which are not thus restricted in their vertical range, even in the same formations in which definite zones occur.

The number of species included under the general name *Ammonites* is so large, that it is absolutely necessary to break up the genus in some manner or another, and various

modes of subdivision have been adopted by different palæontologists. In one system, the principal character relied

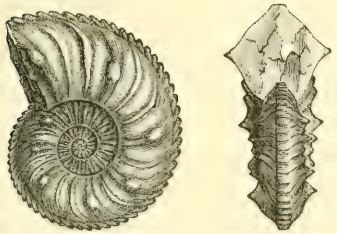


Fig. 468.—*Ammonites margaritatus.* Lias.

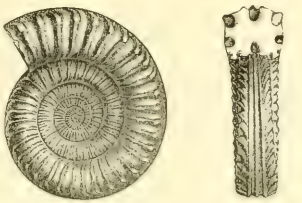


Fig. 469.—*Ammonites bisulcatus.* Lias.

upon is the form of the dorsal side or convex margin of the shell, and in accordance with this the genus may be divided into the following groups (Pictet) :—

Section A. *Back with an entire keel.*

1. *Arietes* . . . Lower Oolites.—*Ex.* A. bisulcatus.
2. *Falciferi* . . Lower Oolites.—*Ex.* A. serpentinus.
3. *Cristati* . . . Cretaceous.—*Ex.* A. inflatus.

Section B. *Back crenated or tuberculated.*

4. *Amalthei* . . . . . Oolites. — *Ex.* A. cordatus.
5. *Pulchelli* or *Rhotomagenses* . . Cretaceous.—*Ex.* A. crenatus.

Section C. *Back compressed and sharp.*

6. *Clypeiformi* (or *Disci*) . . . Oolites.—*Ex.* A. discus.

Section D. *Back channelled.*

7. *Dentati* . . . Oolitic and Cretaceous.—*Ex.* A. Jason.
8. *Gemmati* . . Trias.—*Ex.* A. Aon.

Section E. *Back squared.*

9. *Flexuosi* . . . Cretaceous.—*Ex.* A. radiatus.
10. *Compressi* . . Cretaceous.—*Ex.* A. Beaumontianus.
11. *Armati* . . . Oolitic.—*Ex.* A. perarmatus.
12. *Angulicostati* . Oolitic and Cretaceous.—*Ex.* A. Milletianus.

Section F. *Back round.*

13. *Capricorni* . . Lias.—*Ex.* A. planicostatus.
14. *Heterophylli* . Oolitic.—*Ex.* A. heterophyllus.
15. *Ligati* . . . Cretaceous.—*Ex.* A. Mayorianus.
16. *Planulati* . . Oolitic.—*Ex.* A. annulatus.

17. *Coronati* . . Oolitic.—*Ex.* A. Humphresianus.
18. *Macrocephali* . Oolitic and Cretaceous.—*Ex.* A. microstoma.
19. *Globosi* . . . Trias.—*Ex.* A. globus.
20. *Fimbriati* . . Jurassic and Cretaceous.—*Ex.* A. subfimbriatus.

The more modern and more generally accepted subdivisions of *Ammonites* are founded principally upon differences in the form of the body-chamber, the shape of the aperture of the shell, and the presence or absence of the structure which will be immediately described as the *Aptychus*, together with the characters of this organ when present. As regards the first of these features, the length of the body-chamber is very variable in different forms of *Ammonites*, and this variability must have been correlated with corresponding important differences in the organisation of the animal itself. In a great many forms, especially those from the Jurassic and Cretaceous formations, the body-chamber is comparatively long, varying from half a whorl to two-thirds of a whorl, or reaching a whole whorl or more in length. In other forms, however, the chamber of habitation is very short.

The shape of the aperture of the shell is likewise very variable. In many forms there is a constriction of the shell just behind the aperture; and the transverse sulci, with intervening ribs, which cross the shell of many species, are simply remains of the constrictions marking the position of the aperture at former periods of growth. In other cases, the aperture of the shell is furnished with larger or smaller prolongations or processes, which may be situated on the sides of the mouth, or on its upper aspect, or, rarely, below. When a shelly process exists upon the upper side of the aperture, it probably serves, as supposed by Mr J. F. Blake, to protect the funnel; but the object of the much commoner lateral processes (as seen in *Ammonites Jason*, fig. 466), and of the unusual lower extensions of the shell, must be regarded as quite uncertain.

Lastly, we have briefly to consider the nature and probable function of the extraordinary organ known as the *Aptychus*. The structure so called (fig. 470) is a calcareous or horny plate, which has commonly been found just outside

the aperture of the Ammonites, or which may occur in deposits which contain Ammonites. When the *Aptychus* is calcareous, it consists of two shelly plates, divided by a median suture (fig. 470), smooth or variously sculptured on one side, and marked internally by concentric lines of growth. *Aptychi* of this nature have been described as distinct fossils under the name of *Trigonellites*. In other cases, the *Aptychus* is of a corneous consistence, and it is then in the form of an undivided plate. *Aptychi* of this kind are known by the general name of *Anaptychus*. What may be the precise nature of these extraordinary structures has been a matter of much dispute. They have been supposed to be Crustaceous and allied to the recent Barnacles; but there can no longer be any doubt as to their truly belonging to the Ammonites, with which they are associated. Admitting this connection, the two principal theories as to the nature and functions of the *Aptychus* would regard this structure either as being an *operculum*, similar to that of the Gasteropods, or as forming a protective plate to the nidamental gland. The general view, perhaps, is that it is an operculum, though there are considerable difficulties in the way of an unconditional acceptance of this opinion. Without entering further into these, we must not omit to notice the important fact that the theory that the *Aptychus* is a protective plate developed in the walls of the nidamental gland, of necessity carries with it the conclusion that all examples of *Ammonites* possessing this structure must be *females*. We must also not forget that many Ammonites have never been shown to be accompanied by any structures of the nature of the *Aptychus*, and may therefore fairly be judged not to have possessed one.

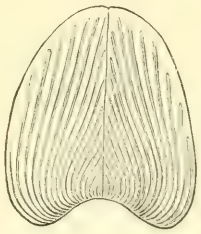


Fig. 470.—Calcareous and divided *Aptychus* (*Trigonellites lamellosus*) of an Ammonite. Jurassic. (After Woodward.)

It would occupy too much space here to enter at any length into the subdivisions of the genus *Ammonites* which are based upon the considerations above mentioned, and

which are now generally accepted; and it is the less necessary to do so, as it must be admitted that it is generally impossible to refer particular specimens to these sections, unless they are in a state of unusually complete preservation, or unless the observer be provided with a very extensive *suite* of examples of a given form. It may be of value, however, to reproduce the classificatory table of the sections of *Ammonites* adopted by M. E. Favre (see *Bull. de la Soc. Géol. de France*, ser. 3, vol. i. p. 353):—

SUBDIVISIONS OF AMMONITES.

Section I.—No Aptychus.

a. Body-chamber short; the upper side of the aperture prolonged.	*Phylloceras.* Trias to Cretaceous.
b. Body-chamber short; the aperture prolonged below.	*Lytoceras.* Trias to Cretaceous.
c. Chamber very long, extending over one and a half to two whorls.	*Arcestes.* Trias. *Pinacoceras.* Trias.
d. Body-chamber short; margin of aperture falciform; mouth prolonged above; ornaments of the shell like those of the Argonaut.	*Trachyceras.* Trias.

Section II.—An Aptychus present.

A. The Aptychus corneous and undivided (*Anaptychus*):—

a. Body-chamber extending over one whorl and a half or two whorls. The upper margin of the aperture prolonged into a point.	*Aricites* (Waagen). Triassic and Jurassic.
b. Body-chamber extending over two-thirds of a whorl or one whorl; the upper margin of the aperture prolonged into a rounded extension.	*Egoceras* (Waagen). Triassic and Jurassic.
c. Body-chamber short, extending over one-half or two-thirds of a whorl; the upper margin of the aperture prolonged greatly.	*Amaltheus.* Triassic to Cretaceous.
(*d.* The *Aptychus* in one piece but calcareous; shell unknown. *Aptychus Numida.* Cretaceous.)	

B. Aptychus calcareous, of two pieces:—

a. The *Aptychus* furrowed externally.

1. *Aptychus* thin; body-chamber short; aperture with a falciform margin prolonged above into a point. — *Harpoceras.* Jurassic.
2. *Aptychus* thick; body-chamber short, with a falciform margin, prolonged above into a rounded appendage. — *Oppelia.* Jurassic and Cretaceous.
3. Body-chamber short; a groove or dilatation near the aperture; the aperture with lateral and superior extensions, the latter rounded. — *Haploceras.* Jurassic and Cretaceous.

b. *Aptychus* thin; granulated externally.

1. Body-chamber long; the mouth simple, or with lateral extensions. — *Stephanoceras.* Jurassic and Cretaceous.
2. Body-chamber long; the aperture constricted by a furrow, or furnished with lateral extensions. — *Perisphinctes.* Jurassic and Cretaceous.
3. — *Peltoceras.* Jurassic.
4. Body-chamber short; the aperture simple or provided with lateral extensions. — *Cosmoceras.* Jurassic.

c. *Aptychus* thick, smooth, and externally punctate.

1. Body-chamber long; a large umbilicus; the shell furrowed; the margin of the aperture with a pointed upper prolongation. — *Simoceras.* Tithonic.
2. Body-chamber short; the margin of the aperture generally simple. — *Aspidoceras.* Jurassic and Cretaceous.

Leaving the great genus *Ammonites,* we have a number of more or less closely allied types to consider, of which only the more important ones can be alluded to here.

In the genus *Crioceras* (fig. 473, *d*) are included forms which resemble the Ammonites in all essential characters, but in which the volutions of the shell are not contiguous. The shell, therefore, is discoidal, with separate whorls, thus corresponding with *Gyroceras* amongst the series of the *Nautilidæ.* All the known species of *Crioceras* belong to the Cretaceous period, ranging from the Lower Greensand to the Gault.

Choristoceras, of the Trias, resembles *Crioceras* in shape, but the septa and sutures have the form characteristic of *Ceratites.*

In the genus *Toxoceras* the shell is simply arcuate, or bent

like a horn, and is never spirally rolled up; so that this genus represents *Cyrtoceras* in the series of the *Nautilidæ*. The species of *Toxoceras* range from the Lower Oolites to the Gault, but the genus is characteristically Cretaceous.

In the genus *Ancyloceras* (fig. 471) the shell at first re-

Fig. 471.—*Ancyloceras Matheronianus*. Gault.

sembles that of *Crioceras*, consisting of several volutions which are coiled into a flat spiral, but which are not in contact with one another. The shell differs from *Crioceras*, however, in the fact that the last volution is produced at a tangent, and is ultimately bent back in the form of a crosier. The species of *Ancyloceras* are Jurassic and Cretaceous, ranging from the Inferior Oolite to the Chalk.

In the genus *Scaphites* (fig. 473, *e*) the shell resembles that of *Ancyloceras* in consisting of a series of volutions coiled into a flat spiral, and having the last volution detached from the others, produced, and ultimately bent back in the form of a crosier. *Scaphites* differs from *Ancyloceras* in the fact that the volutions of the enrolled part of the shell are in contact, instead of being separate as they are in the latter. The produced whorl, also, is rarely of any great length, but is speedily bent back upon itself. All the species of *Scaphites* are Cretaceous, ranging from the Lower Greensand to the Chalk.

In the genus *Helicoceras* the shell is coiled into a turreted spiral, the volutions of which are not contiguous. The shell is also left-handed or "sinistral." With the exception of a single species from the Inferior Oolite, all the species of *Helicoceras* belong to the Cretaceous period.

In the genus *Turrilites* the shell agrees with that of the preceding in being composed of volutions which pass ob-

liquely round a central axis (fig. 472), so as to form a turreted spiral. The shell is also left-handed or "sinistral." In *Turrilites*, however, the whorls of the shell are in contact, instead of being disconnected as they are in *Helicoceras*. The

Fig. 472.—*Turrilites catenatus*. The lower figure represents the entire shell; the upper figure represents the base of the shell seen from below. Gault.

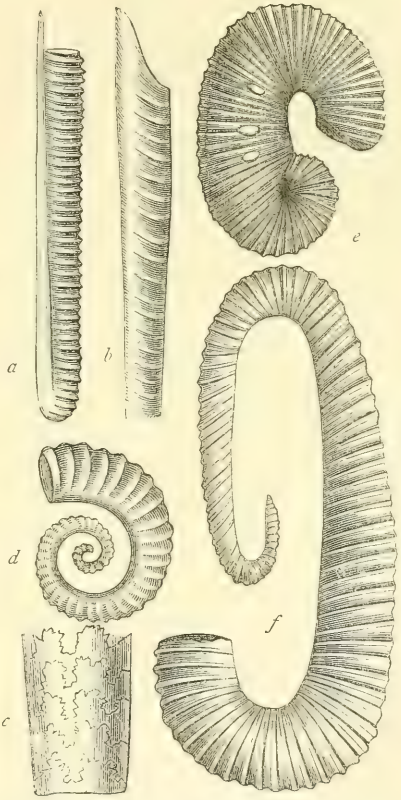


Fig. 473.—*a*, *Ptychoceras Emericianum*, reduced—Lower Greensand; *b*, *Baculites anceps*, reduced—Chalk; *c*, Portion of the same, showing the folded edges of the septa; *d*, *Crioceras cristatum*, reduced—Gault; *e*, *Scaphites æqualis*, natural size—Chalk; *f*, *Hamites rotundus*, restored—Gault.

genus corresponds with *Trochoceras* in the series of the *Nautilidæ*. All the species of *Turrilites* are Cretaceous, ranging from the Gault to the Chalk. *Cochloceras*, of the Trias,

resembles *Turrilites* in shape, but the sutures are simply lobed and are not foliaceous.

In the genus *Hamites* (fig. 473, *f*) the shell is an extremely-elongated cone, which is bent upon itself more than once, in a hook-like manner, all the volutions being separate. Numerous species of *Hamites* are known, all of them being Cretaceous, and ranging from the Lower Greensand to the Chalk. *Hamulina*, of the Cretaceous, has the shell bent once upon itself, as in *Ptychoceras*, but the reflected portions of the shell are not in contact with one another.

In the genus *Ptychoceras* (fig. 473, *a*) the shell is also a much-elongated cone, which is simply bent upon itself once, the two straight portions of the shell being in contact. The range of this genus is the same as that of *Hamites*, extending from the Lower Greensand to the Chalk.

Lastly, in the genus *Baculites* (fig. 473, *b* and *c*) the shell is simply a straight elongated cone, not bent in any way. *Baculites* corresponds, therefore, with *Orthoceras* in the series of the *Nautilidæ*. The range of *Baculites* is the same as that of the preceding—from the Lower Greensand to the Chalk; but the genus is most abundant in the Chalk itself.

CHAPTER XXVIII.

DIBRANCHIATE CEPHALOPODS.

The Dibranchiate Cephalopods or Cuttle-fishes are characterised as being *swimming animals, almost invariably naked, with never more than eight or ten arms, which are always provided with suckers. There are two branchiæ, which are furnished with branchial hearts; an ink-sac is always present; the funnel is a complete tube, and the shell is internal, or, if external, is not chambered.*

The Cuttle-fishes are rapacious and active animals, swimming freely by means of the jet of water expelled from the funnel. The arms constitute powerful offensive weapons, being excessively tenacious in their hold, and being sometimes provided with a sharp claw in the centre of each sucker. They are mostly nocturnal or crepuscular animals, and they sometimes attain to a great size. They may be divided into two sections, *Octopoda* and *Decapoda*, according as they have simply eight arms, or eight arms and two additional "tentacles."

The parts of a Dibranchiate Cephalopod which may be preserved in a fossil condition are the mandibles, the ink-sac, the shell (if such be present), and the internal skeleton. The occurrence of the ink-sacs of Dibranchiate Cephalopods in a fossil state has been already spoken of (p. 55), and need not be further noticed here. An external shell is present only in the Argonaut amongst living Cuttle-fishes, and similar structures are of rare occurrence as fossils in some of the youngest portions of the earth's crust. The

internal skeleton of the Cuttle-fishes differs very much in its characters in different cases. In the Calamaries the skeleton is in the form of a horny "pen," consisting of a median shaft and of two lateral expansions or wings (fig. 447, *b*). In the *Sepiadæ* (fig. 447, *a*) the skeleton has the form of a broad, laminated, calcareous plate, having a more or less perfectly chambered apex or "mucro." In the singular *Spirula* (fig. 447, *c* and *d*) the skeleton has the form of a chambered tube coiled into a spiral, the coils of which are separate from one another. Lastly, in the extinct family of the *Belemnitidæ*, there was a complicated internal support. It is, then, chiefly from the preservation of their internal skeletons that the Dibranchiate Cephalopods are known to have existed in past periods of the earth's history. In addition, however, to the skeleton and ink-bag, cases are not altogether unknown in which the hooks of the suckers, and even the outlines of the arms and body, have been preserved in a fossil condition.

As regards their general distribution in time, the record of the Dibranchiate Cephalopods is much less complete than that of the *Tetrabranchiata*. In the vast series of the Palæozoic formations no trace has ever been discovered of the existence of any member of this order. Shortly after the commencement of the Mesozoic period appear the first Belemnites; and all the Secondary formations after the oldest teem with the remains of this family of the *Dibranchiata*. Remains of the living families of the *Teuthidæ* and *Sepiadæ* are also not unknown in the Mesozoic rocks, but it is only recently that any trace of the great group of the *Belemnitidæ* has been detected in Tertiary deposits. Upon the whole, the order must be regarded as having attained its maximum at the present day. In the following are given the characters, chief genera, and distribution in time of the families of the Dibranchiate Cephalopods.

Section A. Octopoda.—The Cephalopods comprised in this section are distinguished by the possession of eight arms, which are provided with sessile suckers. The body is short and bursiform, ordinarily without fins. The shell is internal and rudimentary; in one instance only (Argonaut) external.

Fam. 1. Argonautidæ.—Female provided with a delicate,

symmetrical, involuted shell (fig. 474), which is secreted by the webbed extremities of the two dorsal arms, and is not attached in any way to the body of the animal. Male much smaller than the female, shell-less. This family includes only the single genus *Argonauta* (the Paper Nautilus). One or two species of Argonaut have been discovered in the Pliocene Tertiary.

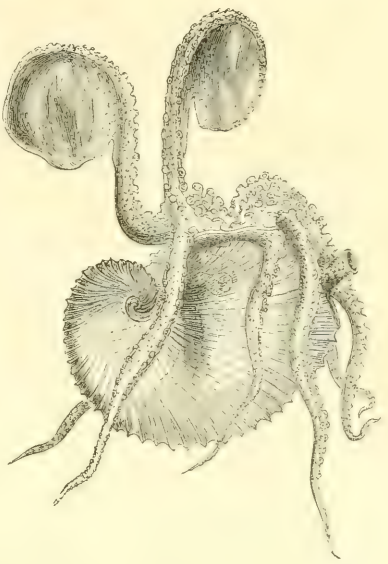


Fig. 474. — *Argonauta argo*, the "Paper Nautilus," female. The animal is represented in its shell, but the webbed dorsal arms are separated from the shell, which they ordinarily embrace.

Fam. 2. Octopodidæ. — Shell internal, rudimentary, represented by two short styles encysted in the substance of the mantle. This family includes the living Poulpes and their allies, but has no fossil representatives.

Section B. Decapoda. —The Cuttle-fishes of this section have eight "arms" and two additional "tentacles," which are much longer than the true arms, and carry suckers on their extremities only, which are expanded and club-shaped. The suckers are pedunculated, the body is furnished with lateral fins, and the shell is always internal.

Fam. 3. Teuthidæ.—Shell consisting of an internal horny "pen" or "gladius," composed of a central shaft and two lateral wings. Several of such pens may exist in a single individual, packed one behind the other. Fins mostly terminal and angular. This family comprises the living Calamaries and Squids, and the following fossil genera have been founded upon "pens" which have been discovered in various Secondary deposits :—

a. Teudopsis.—Pen lanceolate, produced in front, dilated

and spatulate behind. Five species of this genus have been described from the Lias.

b. Belotcuthis.—Pen lanceolate, pointed in front, with two small wing-like expansions behind (fig. 475). Six species have been described by Count Münster from the Upper Lias of Würtemberg.

Fig. 475.—*Belotcuthis subcostata.* Jurassic (Lias).

c. Phylloteuthis.—Pen corneous, thin, and sub-ovate, slightly concave below and convex above, the anterior end narrow. The known forms are from the Cretaceous.

d. Leptoteuthis.—Pen horny, hastate, broad in front, pointed behind. A single species is known from the Oxford Clay (Jurassic).

e. Besides the above, remains found in the Jurassic rocks have been referred to the living genera *Enoploteuthis* and *Ommastrephes;* and the extinct genus *Acanthoteuthis* has also been placed in this family.

Fam. 4. Sepiadæ.—Internal skeleton (fig. 447, *a*) in the form of a broad, laminated, calcareous plate, with an imperfectly chambered apex (or "mucro"). The chambered portion of the skeleton corresponds with the "phragmacone" of the Belemnites. The fossil species of this family range from the Middle Oolites upwards, and belong to the following three genera:—

a. Sepia.—Shell broad and thick in front, laminated, and terminating in a prominent mucro. The fossil forms belong to the Oxford Clay (Jurassic) and Eocene Tertiary, and the genus attains its maximum at the present day.

b. Spirulirostra.—The shell (fig. 476) in this singular genus consists of a chambered portion or "phragmacone" coiled into a spiral, the volutions of which are separated. This is lodged in a pointed calcareous portion or "rostrum." The only known species of this genus is found in the Miocene Tertiary.

c. Beloptera.—Shell consisting of a nearly straight chambered portion or "phragmacone" perforated by a siphuncle, and lodged in a pointed calcareous rostrum which is furnished with lateral wings. Two species only of this genus are known, both from the Eocene Tertiary. It seems

quite probable that this genus really belongs to the *Belemnitidæ*.

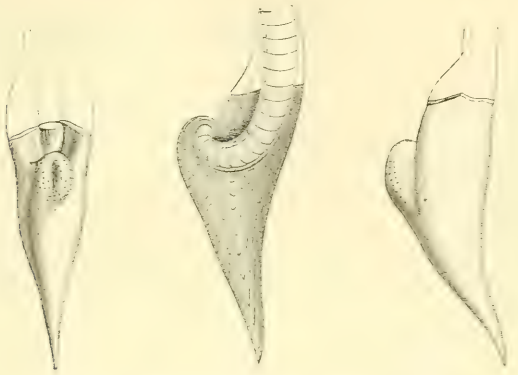


Fig. 476.—*Spirulirostra Bellardii*. Miocene Tertiary.

d. Belemnosis.—This genus has been founded for the reception of an Eocene fossil closely resembling *Beloptera*, but differing in not possessing any lateral expansions. This genus also probably belongs to the family *Belemnitidæ*.

Fam. 5. Spirulidæ.—Shell (fig. 447, *c*) nacreous, discoidal, composed of volutions which are not in contact with one another. The shell is divided into a series of air-chambers by curved shelly partitions, pierced by a ventral tube or "siphuncle." The entire shell corresponds with the "phragmacone" of the skeleton of the Belemnites. *Spirulirostra* and *Beloptera* are often referred to this family; but if these be placed in the *Sepiadæ*, the family of the *Spirulida* is then without any known fossil representative.

Fam. 6. Belemnitidæ.—Shell internal, composed of a conical chambered portion ("phragmacone"), with a marginal or ventral siphuncle, lodged in a cylindrical fibrous "guard," and produced in front into a thin horny or shelly plate or "pen" (the "pro-ostracum"). The *Belemnitidæ* are almost exclusively confined to the Secondary rocks, ranging from the top of the Trias to the Chalk, inclusive. Quite recently Professor Tate has described a species of Belemnite from strata of supposed Tertiary age in Australia; and another form has been recorded from Eocene deposits in Europe.

With these exceptions, however, no Tertiary examples of the family are known, and the group has no living representatives. The following are the more important genera belonging to this family :—

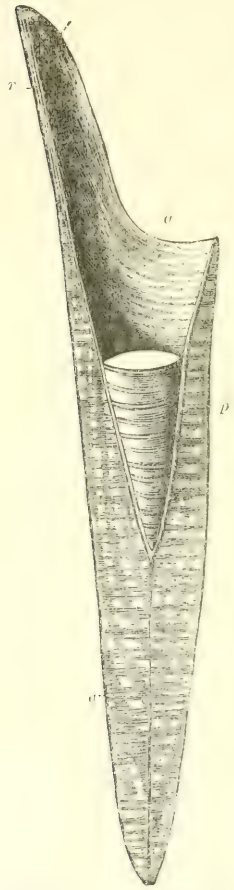


Fig 477.—Diagram of Belemnite (after Professor Phillips). *r*, Horny or shelly pen or "pro-ostracum;" *p*, Chambered "phragmacone" in its cavity (*o*) or "alveolus;" *g*, "Guard."

a. Belemnites.—The skeleton of the Belemnite consists of a sub-cylindrical, longer or shorter, fibrous body (figs. 477, 478), which is termed the "rostrum" or "guard." The length of the guard varies very much in different cases, and it is the part of the Belemnite which is most commonly found in a fossil condition. At the front or broad end, the guard is hollowed out into a conical excavation, which is termed the "alveolus." Within the alveolus, in perfect specimens, is contained the "phragmacone." This consists of a conical series of chambers, separated from one another by curved shelly partitions or septa, which are perforated by apertures for the passage of the "siphuncle." The siphuncle traverses the middle of the ventral wall of the phragmacone, and the whole series of chambers is enclosed in a thin shell-wall (the "conotheca" of Huxley). Anteriorly the conotheca or investment of the phragmacone is prolonged forwards into a horny or shelly plate, which corresponds with part of the "pen" of the Calamaries, and which is termed the "pro-ostracum" (fig. 477, *r*). The form of the "pro-ostracum" varies greatly in different cases, and it affords important characters in the discrimination of specific and generic forms in the *Belemnitidæ*. Owing, however, to its extreme tenuity,

it is rarely found preserved in a fossil condition, and its value to the working palæontologist is thus greatly reduced.

Not only is the internal skeleton of the Belemnite known, but various specimens have been discovered, from which much has been learnt as to other points of its anatomy. Thus we know that the body (fig. 478, A) was furnished with lateral fins, that there were eight arms and two longer "tentacles," that the suckers were provided with horny hooks, and that there was a large ink-sac, together with horny mandibles. Most of the specimens here alluded to belong to *Belemnoteuthis*, but *Belemnites* proper was doubtless built upon essentially the same plan.

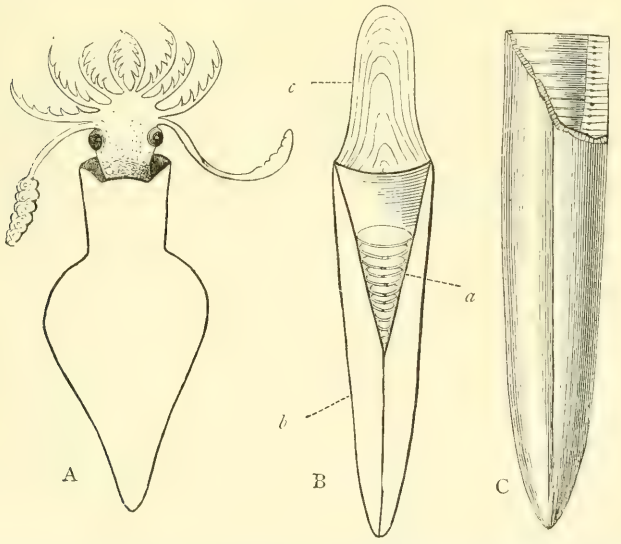


Fig. 478.—A, Restoration of the animal of the Belemnite; B, Diagram showing the complete skeleton of a Belemnite, consisting of the chambered phragmacone (*a*), the guard (*b*), and the horny pen (*c*); C, Specimen of *Belemnites canaliculatus*, from the Inferior Oolite. (After Phillips.)

The following table of the sections and sub-sections of the species of the genus *Belemnites* is the one given by Dr S. P. Woodward:—

Section I. Acœli.
Without dorsal or ventral grooves.
Sub-section 1. *Acuarii.*
Without lateral furrows, but often channelled at the extreme point. (*Ex. B. acuarius.* Lias.)
Sub-section 2. *Clavati.*
With lateral furrows. (*Ex. B. clavatus.* Lias.)
Section II. Gastrocœli.
Ventral groove distinct.
Sub-section 1. *Canaliculati.*
No lateral furrows. (*Ex. B. canaliculatus.* Inf. Oolite.)
Sub-section 2. *Hastati.*
Lateral furrows distinct. (*Ex. B. hastatus.* Oolite.)
Section III. Notocœli.
With a dorsal groove, and furrowed on each side. (*Ex. B. dilatatus.* Neocomian.)

The species of the genus *Belemnites* range from the top of the Trias, where the earliest forms appear, to the Upper Greensand, in which the genus, with one or two exceptions, finally disappears. The species are most numerous in the Jurassic rocks, and often occur in the greatest abundance in particular beds or particular localities. It would seem not improbable that the genus *Belopteva*, before noticed, should be referred to the *Belemnitidæ*, and the genus *Belemnosepia* (or *Geoteuthis*), formerly referred to the *Teuthidæ*, appears to be almost certainly referable here.

Fig. 479.—*Belemnitella mucronata.* Chalk.

b. Belemnitella.—In this genus (fig. 479) the skeleton is very similar in its general arrangement to that of *Belemnites;* but there is a straight fissure in the guard, at its upper end, on the ventral side of the wall of the alveolus, and the surface is marked with distinct vascular impressions. The species of this genus are exclusively Cretaceous, and are only found in the upper portion of this formation, ranging from the Upper Greensand to the Chalk.

c. Belemnoteuthis.—"*Shell* consisting of a *phragmacone*, like that of the Belemnite; a horny dorsal *pen* with obscure lateral bands; and a thin fibrous *guard*, with two diverging

ridges on the dorsal side. *Animal* provided with *arms* and *tentacles* of nearly equal length, furnished with a double alternating series of horny hooks, from 20 to 40 pairs on each arm; *mantle* free all round; *fins* large, medio-dorsal" (Woodward). Only one species is known, from the Oxford Clay (Middle Oolites). High authorities, such as Owen and D'Orbigny, question the validity of this genus, and regard it as being founded upon specimens of *Belemnites*.

d. Xiphoteuthis.—Guard narrow and cylindrical, containing a very long, deep-chambered, narrow phragmacone. Pro-ostracum greatly developed (nearly a foot in length), very narrow at its base, widening out anteriorly, and finally terminating in a pointed apex. Only a single species is known, from the Lias.

e. In addition to the above, the Cretaceous genus *Conoteuthis* and the Jurassic *Plesioteuthis* are probably really referable to the *Belemnitidæ;* and high authorities place here the Tertiary genera *Belopteva* and *Belemnosis*. The Jurassic *Acanthoteuthis* is founded upon horny hooks, which were probably attached to the suckers of *Belemnites*.

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CHAPTER XXIX.

SUB-KINGDOM VERTEBRATA.

The sub-kingdom *Vertebrata* may be shortly defined as including *animals in which the body is composed of a succession of definite segments, arranged along a longitudinal axis; the main masses of the nervous system (brain and spinal cord) are situated along the dorsal surface of the body, and are completely shut off from the general body-cavity. The limbs are never more than four in number, and are always turned away from that aspect of the body upon which the main masses of the nervous system are situated. In all, the nervous axis is primitively supported by a cellular rod, which is termed the "notochord;" but in most the notochord is replaced in the adult by the bony axis known as the "spine" or "vertebral column."*

The past existence of Vertebrate animals is chiefly recognised by the preservation of their hard structures. These hard structures are of two kinds—some belonging to the internal or true skeleton (endoskeleton), others being of the nature of horny or bony plates, scales, or appendages of various kinds, developed in the integument (exoskeleton). The nature of the exoskeleton in the Vertebrates differs very much in different cases, and it will be considered when treating of the separate groups. It will be well, however, to give an extremely general and brief view of the structure of the endoskeleton, taking for this purpose a Mammal as a typical form. In this way the student will be enabled readily to trace the modifications of the skeleton in the lower forms, and will without difficulty comprehend the

terms which are necessarily employed in the definitions of the various groups. It may be added here, before proceeding further, that it does not seem requisite to treat the *Vertebrata* with the same fulness as the *Invertebrata*. The fossil remains of Vertebrates are in many cases of the highest theoretical interest, but they come much less frequently under the notice of the ordinary student than do the remains of the Invertebrates. No practical study, also, of the fossil Vertebrates can be carried out without a considerable acquaintance with Comparative Osteology. Lastly, the remains of Vertebrate animals generally occur in such a fragmentary condition that a sufficient series of specimens for profitable study can rarely be obtained, except under peculiarly favourable circumstances, in special cases, or where access can be had to a first-rate museum. For these and other reasons it is thought enough, in a treatise intended for the working palæontologist, to give a general account of each class of the *Vertebrata*, with definitions of the orders, and a brief notice of the leading forms of each. Only in cases of special interest will any details of a more minute character than the above be given.

The *skeleton* of the *Vertebrata* may be regarded as consisting essentially of the bones which go to form the head and trunk on the one hand (sometimes called the "axial" skeleton), and of those which form the supports for the limbs ("appendicular" skeleton) on the other hand. The bones of the head and trunk may be looked upon as essentially composed of a series of bony rings or segments, arranged longitudinally, one behind the other. Anteriorly these segments are much expanded, and likewise much modified, to form the bony case which encloses the brain, and which is termed the *cranium* or skull. Behind the head the segments enclose a much smaller cavity, which is called the "neural" or spinal canal, as it encloses the spinal cord; and they are arranged one behind the other, forming the vertebral column. The segments which form the vertebral column are called "vertebræ," and they have the following general structure: Each vertebra (fig. 480, A) consists of a central piece, which is the fundamental and essential element of the vertebra,

and is known as the "body" or "centrum" (*c*). From the upper or posterior surface of the centrum spring two bony arches (*n, n*), which are called the "neural arches" or "neurapophyses," because they form with the body a canal—the "neural canal"—which encloses the spinal cord. From the point where the neural arches meet behind, there is usually developed a longer or shorter spine, which is termed the "spinous process" or "neural spine" (*s*). From the neural arches there are also developed in the typical vertebra two processes (*a, a*), which are known as the "articular" processes, or "zygapophyses." The vertebræ are united to one another partly by these, but to a greater extent by the bodies or "centra." From the sides of the vertebral body, at the point of junction with the neural arches, there proceed two lateral processes (*d, d*), which are known as the "transverse processes."

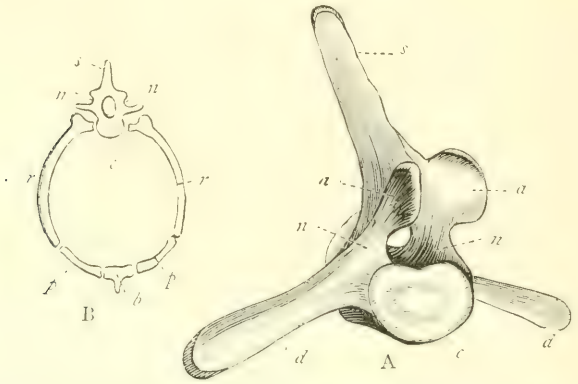

Fig. 480.—A, Lumbar vertebra of a Whale: *c*, Body or centrum; *n, n*, Neural arches; *s*, Neural spine; *a, a*, Articular processes; *d, d*, Transverse processes. B, Diagram of a thoracic vertebra: *c*, Centrum; *n, n*, Neural arches enclosing the neural canal; *s*, Neural spine; *r, r*, Ribs, assisting in the formation of the hæmal arch; *p, p*, Costal cartilages; *b*, Sternum, with hæmal spine. (After Owen.)

These elements form the *vertebra* of the human anatomist, but the "vertebra" of the transcendental anatomist is completed by a second arch which is placed beneath the body of the vertebra, and which is called the "hæmal" arch, as it includes and protects the main organs of the circulation. This second arch is often only recognisable with great difficulty, as its parts are generally much modi-

fied, but a good example may be obtained in the human thorax, or in the caudal vertebra of a bony fish.

As a general rule, the vertebral column is divisible into a number of distinct regions, of which the following are recognisable in man and in the higher *Vertebrata:* 1. A series of vertebræ which compose the neck, and constitute the "cervical region" of the spine (fig. 481, *c*). 2. A number of vertebræ which usually carry well-developed ribs, and form the "dorsal region" (*d*). 3. A series of vertebræ which form the region of the loins, or "lumbar region" (*b*). 4. A greater or less number of vertebræ which constitute the "sacral region," and are usually amalgamated or "anchy-

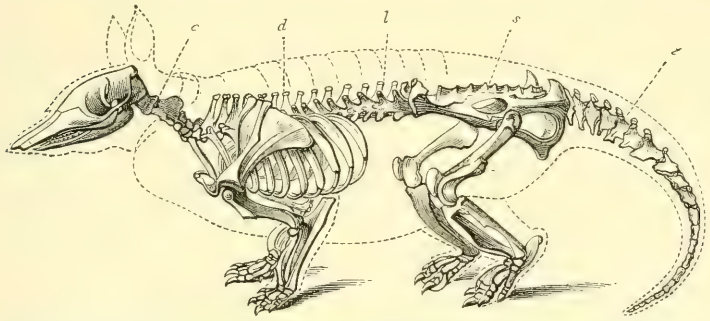

Fig. 481.—Skeleton of an Armadillo, showing the regions of the vertebral column. *c*, Cervical region; *d*, Dorsal region; *l*, Lumbar region; *s*, Sacral region; *t*, Caudal region or tail.

losed" together to form a single bone, the "sacrum" (*s*). 5. The spinal column is completed by a variable number of vertebræ which constitute the "caudal" region or tail (*t*).

As regards the skull of the Vertebrates, the most important points to be noticed are the manner in which the cranium articulates with the vertebral column, and the structure of the lower jaw or "mandible." In Birds and Reptiles the skull articulates with the first vertebra of the neck by means of a single articulating surface or "condyle," carried upon the occipital bone. In the Amphibians, again, and in the Mammals, there are *two* "occipital condyles," by which the skull is jointed to the neck. The lower jaw is sometimes wanting, but, when present, it consists in all *Vertebrata* of two halves or "rami," which are

united to one another in front, and articulate separately with the skull behind. In many cases, each half, or "ramus," of the lower jaw consists of several pieces united to one another by sutures; but in the *Mammalia* each ramus consists of no more than a single piece. The two rami are very variously connected with one another, being sometimes only joined by ligaments and muscles, sometimes united by cartilage or by bony suture, and sometimes fused or anchylosed with one another, so as to leave no evidence of their true composition. The mode by which each ramus of the lower jaw articulates with the skull also varies. In the *Mammalia* the lower jaw articulates with a cavity formed on what is known to human anatomists as the temporal bone; but in Birds and Reptiles the lower jaw articulates with the skull, not directly, but by the intervention of a special bone, known as the "quadrate bone" or "*os quadratum*."

As regards the *limbs* of Vertebrates, whilst many differences exist, which will be afterwards noticed, there is a general agreement in the parts of which they are composed. As a rule, each pair of limbs is joined to the trunk by means of a series of bones which also correspond to one another in general structure. The fore-limbs, often called the "pectoral" limbs, are united with the trunk by means of a bony arch, which is called the "pectoral" or "scapular" arch; whilst the hind-limbs are similarly connected with the trunk by means of the "pelvic arch." In giving a general description of the parts which compose the limbs and their supporting arches, it will be best to take the case of a Mammal, and the departures from this type will then be readily recognised.

The pectoral or scapular arch consists usually of three bones, the "scapula" or shoulder-blade, the "coracoid," and the "clavicle" or collar-bone; but in the great majority of the Mammals, the coracoid is anchylosed with the scapula, of which it forms a mere process. The scapula or shoulder-blade (fig. 482, *s*) is usually placed outside the ribs, and it forms, either alone or in conjunction with the coracoidal element of the shoulder-girdle, the cavity with which the upper arm is articulated. The coracoid, though rarely existing as a distinct bone in the Mammals, plays a very important part in other

Vertebrates. The clavicles are often wanting, or rudimentary, and they are the least essential elements of the scapular arch. The fore-limb proper consists, firstly, of a single bone which forms the upper arm, and which is known as the *humerus* (*h*). This articulates above the shoulder-girdle, and is followed below by the fore-arm, which consists of two bones, called

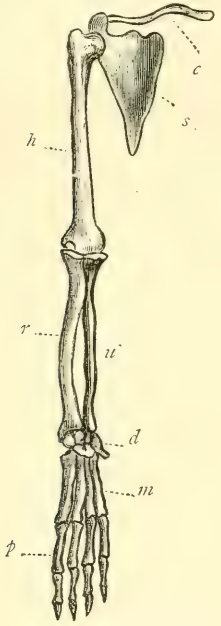

Fig. 482.—Pectoral limb (arm) of Chimpanzee (after Owen). *c*, Clavicle; *s*, Scapula or shoulder-blade; *h*, Humerus; *r*, Radius; *u*, Ulna; *d*, Bones of the wrist, or carpus; *m*, Metacarpus; *p*, Phalanges of the fingers.

Fig. 483.—Hind-limb of the Chimpanzee. *i*, Innominate bone; *f*, Thigh-bone or femur; *t*, Tibia; *s*, Fibula; *r*, Bones of the ankle, or tarsus; *m*, Metatarsus; *p*, Phalanges.

the *radius* and *ulna*. Of these the *radius* is chiefly concerned with carrying the hand. The radius and ulna are followed by the bones of the wrist, which are usually composed of several bones, and constitute what is called the *carpus* (*d*). These support the bones of the root of the hand, which vary in number, but are always more or less cylindrical in shape. They constitute what is called the *metacarpus*. The bones of

the metacarpus carry the digits, which also vary in number, but are composed each of from two to three cylindrical bones, which are known as the *phalanges* (*p*).

Homologous parts are, as a rule, readily recognisable in the hind-limb. The pelvic arch, by which the hind-limb is united with the trunk, consists of three pieces—the *ilium*, *ischium*, and *pubes*—which are usually anchylosed together, and form conjointly what is known as the *innominate bone* (fig. 483, *i*). In most Mammals, the two innominate bones unite in front by a ligamentous or cartilaginous union, and they constitute, with the sacrum, what is known as the *pelvis*. The hind-limb proper consists of the following parts: 1. The thigh-bone or *femur*, corresponding with the humerus in the fore-limb. 2. The bones of the shank, corresponding with the radius and ulna of the fore-limb, and known as the *tibia* and *fibula*. Of these, the tibia is mainly, or altogether, concerned in carrying the foot, and it is thus shown to correspond to the radius, whilst the fibula corresponds to the ulna. 3. The small bones of the ankle, known as the *tarsus*, and varying in number in different cases. 4. A variable number of cylindrical bones (normally five), which are called the *metatarsus*, and which correspond to the metacarpus. 5. Lastly, the metatarsus carries the digits, which consist, each, of from two to three small bones or *phalanges*, as in the fore-limb.

The sub-kingdom Vertebrata is divided into the following five classes:—

1. Pisces (Fishes).—Respiration by means of gills; heart usually two-chambered; an exoskeleton, in the form of horny scales or bony plates, generally present; blood cold. Limbs, when present, in the form of fins, or expansions of the integument supported by bony or cartilaginous spines or "rays."

2. Amphibia (Amphibians).—Respiration at first exclusively by gills, afterwards by lungs, either alone or associated with gills. Heart of the adult three-chambered; blood cold. The skull connected with the vertebral column by two occipital condyles. The limbs, when present, never converted into fins, and composed of the same parts as in the higher Vertebrates.

3. Reptilia (Reptiles).—Respiration aerial, by lungs, and never by gills. Pulmonary and systemic circulations connected together either within the heart or in its immediate neighbourhood. Heart of the adult three-chambered in most; rarely four-chambered. Blood cold. Skull united to the vertebral column by one occipital condyle. Exoskeleton in the form of horny scales or bony plates, or both combined.

4. Aves (Birds).—Respiration aerial, by lungs, and never by gills. Bronchial tubes opening on the surface of the lungs into air-sacs. A greater or less number of the bones almost always hollow and filled with air. The skull connected with the vertebral column by a single occipital condyle. Heart four-chambered; the pulmonary and systemic circulations distinct, and the blood warm. Epidermic appendages in the form of feathers. Pectoral limbs in the form of wings. Animal oviparous.

5. Mammalia (Quadrupeds).—Respiration aerial, by lungs, and never by gills. The terminations of the air-passages (bronchi) never connected with air-sacs. Heart four-chambered; the pulmonary and systemic circulations distinct; the blood warm. Skull connected with the vertebral column by two articulating surfaces or condyles. Some part or other of the integument provided at some time or other with epidermic appendages in the form of hairs. The young nourished for a shorter or longer time by means of a special fluid—the milk,—secreted by special glands—the mammary glands. Animal viviparous.

As regards the general *distribution in time* of the *Vertebrata*, the earliest certain traces of the existence of this subkingdom are found in the Upper Silurian rocks. Here are the remains of Ganoid and Plagiostomous fishes; and we may fairly anticipate that further research will ultimately result in putting back the first appearance of Fishes at any rate to the Lower Silurian. The class of the Amphibians is not known to have come into existence prior to the commencement of the Carboniferous period, but it had attained a great development before the close of this epoch. The class of the true Reptiles is represented by undoubted examples for the first time in the Permian deposits. In the

Mesozoic rocks, however, the development of this class was so great that the Secondary period has been termed the "Age of Reptiles." The class *Aves* is doubtfully represented by footprints in strata of the age of the Trias; but no Palæozoic remains of this class have been as yet detected. The earliest undoubted remains of Birds occur in the Jurassic series, and the class has continued to be represented more or less abundantly to the present day. Lastly, the class of the *Mammalia*, so far as at present known, finds its earliest fossil representative in strata of the age of the Trias (New Red Sandstone). The Mammals, however, cannot be said to be in any way abundant as fossils, till we reach the Eocene Tertiary. From this point onward the remains of Mammals are as abundant as, in the nature of the case, they could reasonably be expected to be.

CHAPTER XXX.

FISHES.

The first class of the *Vertebrata* is that of the Fishes (*Pisces*), which may be broadly defined as including *Vertebrate animals which are provided with gills throughout the whole of life; the heart, when present, consists (with few exceptions) of a single auricle and a single ventricle; the blood is cold; the limbs, when present, are in the form of fins, or expansions of the integument.*

In form, Fishes are adapted for rapid locomotion in water, the shape of the body being such as to give rise to the least possible friction in swimming. To this end also, as well as for purposes of defence, the body is usually enveloped with a coating of scales developed in the inferior or dermal layer of the skin. The more important modifications in the form of these dermal scales are as follows: 1. *Cycloid* scales (fig. 484),

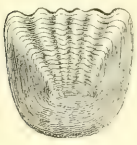

Fig. 484.—Cycloid scale.

Fig. 485.—Ctenoid scale.

Fig. 486.—Ganoid scale.

consisting of thin, flexible, horny scales, circular or elliptical in shape, and having a more or less completely smooth outline. These are the scales which are characteristic of most of the ordinary bony fishes. 2. *Ctenoid* scales (fig. 485),

also consisting of thin horny plates, but having their posterior margins fringed with spines, or cut into comb-like projections. 3. *Ganoid* scales, composed of an inferior layer consisting of bone, covered by a superficial layer of hard polished enamel (the so-called "ganoine"). These scales (fig. 486) are usually much larger and thicker than the ordinary scales, and though they are often articulated to one another by special processes, they only rarely overlap. 4. *Placoid* scales, consisting of detached bony grains, tubercles, or plates, of which the latter are not uncommonly armed with spines.

It is very important for the geologist to recognise the characters of these different scales, as he may have to decide upon the characters of a fossil fish merely from detached scales. Such decisions, however, are always more or less hazardous, since the scales of the different orders of the living fishes are not invariably of the same kind in all the forms of the order. Thus, ganoid scales are not peculiar to the order of the *Ganoid* fishes, but occur also in some of the Bony Fishes (*Teleostei*). The scales, also, form at best but one character, and they can hardly be said to constitute the most important character of any fish. A classification, therefore, which is based primarily upon the nature of the scales, necessarily is more or less "artificial," and is liable to bring into juxtaposition forms which have no real affinity to one another. For these reasons, most zoologists do not accept the classification of the Fishes into the four orders of the *Cycloidei*, *Ctenoidei*, *Ganoidei*, and *Placoidei*, since this classification, though sanctioned by such an eminent authority as Professor Agassiz, is founded solely upon the nature of the integumentary covering. The palæontologist, however, whose materials often consist of nothing more than detached scales, has been not rarely driven, by the necessity of the case, to provisionally classify his specimens in accordance with the nature of these appendages.

As regards their true osseous system or endoskeleton, Fishes vary very widely. In the Lancelet there can hardly be said to be any skeleton, the spinal cord being simply supported by the gelatinous notochord, which remains through-

out life. In others the skeleton remains permanently cartilaginous; in others it is partially cartilaginous and partially ossified; and, lastly, in most modern fishes it is entirely ossified, or converted into bone. Taking a bony fish (fig. 487) as in this respect a typical example of the class, the following are the chief points in the osteology of a fish which require notice:—

The *vertebral column* in a bony fish consists of vertebræ which are hollow at both ends, or biconcave, and are technically said to be "amphicœlous." The cup-like margins of the vertebral bodies are united by ligaments, and the cavities formed between contiguous vertebræ are filled with the gelatinous remains of the notochord. This elastic gelatinous substance acts as a kind of ball-and-socket joint between the bodies of the vertebræ, thus giving the whole spine the extreme mobility which is requisite for animals living in a watery medium. The ossification of the vertebræ is often much more imperfect than the above, but in no case except that of the Bony Pike (*Lepidosteus*) is ossification carried to a greater extent than this. In this fish, however, the vertebral column is composed of "opisthocœlous" vertebræ—that is, of vertebræ the bodies of which are concave behind and convex in front. The entire spinal column is divisible into not more than two distinct regions, an *abdominal* and a *caudal region*. The abdominal vertebræ possess a superior or neural arch (through which passes the spinal cord), a superior spinous process (neural spine), and two transverse processes to which the ribs are usually attached. The caudal vertebræ (fig. 487) have no marked transverse processes; but in addition to the neural arches and spines, they give off an inferior or *hæmal* arch below the body of the vertebræ, and the hæmal arches carry inferior spinous processes (hæmal spines).

The *ribs* of a bony fish are attached to the transverse processes, or to the bodies, of the abdominal vertebræ, in the form of slender curved bones which articulate with no more than one vertebra each, and that only at a single point. Unlike the ribs of the higher Vertebrates, the ribs do not enclose a thoracic cavity, but are simply embedded in the

muscles which bound the abdomen. Usually each rib gives off a spine-like bone, which is directed backwards amongst the muscles. Inferiorly the extremities of the ribs are free, or are rarely united to dermal ossifications in the middle line of the abdomen; but there is never any breast-bone or *sternum* properly so called.

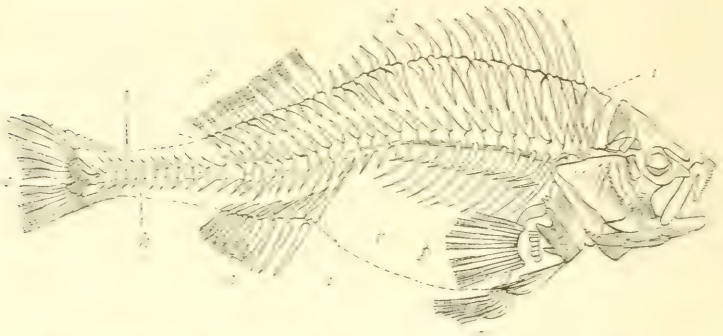

Fig. 487.—Skeleton of the common Perch (*Perca fluviatilis*). *p*, Pectoral fin; *v*, One of the ventral fins; *a*, Anal fin, supported upon interspinous bones (*i*); *c*, Caudal fin; *d*, First dorsal fin; *d'*, Second dorsal fin, both supported upon interspinous bones; *i*, *i*, Interspinous bones; *r*, Ribs; *s*, Spinous processes of vertebræ; *h*, Hæmal processes of vertebræ.

The only remaining bones connected with the skeleton of the trunk are the so-called *interspinous bones* (fig. 487, *i*, *i*). These form a series of dagger-shaped bones plunged in the middle line of the body between the great lateral muscles which make up the greater part of the body of a fish. The internal ends or points of the interspinous bones are attached by ligament to the spinous processes of the vertebræ; whilst to their outer ends are articulated the "rays" of the so-called "median" fins, which will be hereafter described. As a rule, there is only one interspinous bone to each spinous process, but in the Flat-fishes (Sole, Turbot, &c.) there are two.

Besides the fins which represent the limbs (pectoral and ventral fins), fishes possess other fins placed in the middle line of the body, and all of these alike are supported by bony spines or "rays," which are of two kinds, termed respectively "spinous rays" and "soft rays." The "spinous rays" are simple bony spines, apparently composed of a single piece

each, but really consisting of two halves firmly united along the middle line. The "soft rays" are composed of several slender spines proceeding from a common base, and each divided transversely into numerous short pieces. The soft rays occur in many fishes in different fins, but they are invariably found in the caudal fin or tail (fig. 487, *c*). The rays of the median fins, whatever their character may be, always articulate by a hinge-joint with the heads of the interspinous bones.

The *skull* of the bony fishes is an extremely complicated structure, and it is impossible to enter into its composition here. The only portions of the skull which require special mention are the bones which form the gill-cover or operculum. For reasons connected with the respiratory process in fishes, there generally exists between the head and the scapular arch a great cavity or gap on each side, within which are contained the branchiæ. The cavity thus formed opens externally on each side of the neck by a single vertical fissure or "gill-slit," closed by a broad flap, called the "gill-cover" or "operculum," and by a membrane termed the "branchiostegal membrane."

The gill-cover (fig. 488, *p, o, s, i*) is composed of a chain of broad flat bones, termed the opercular bones. Of these, the innermost articulates with the skull (tympano-mandibular arch), and is called the "præ-operculum;" the next is a large bone called the "operculum" proper; and the remaining two bones, called respectively the "sub-operculum" and "inter-operculum," form, with the operculum proper, the edge of the gill-cover. These various bones are united together by membrane, and they form collectively a kind of movable door, by means of which the branchial chamber can be alternately opened and shut. Besides the gill-cover, however, the branchial chamber is closed by a membrane called the "branchiostegal membrane," which is attached to the os hyoides. This membrane is supported and spread out by a number of slender curved spines, which are attached to the lateral branches of the hyoid bone, act very much as the ribs of an umbrella, and known as the "branchiostegal rays" (fig. 488, *d*). In many Ganoid fishes the place of the

"branchiostegal rays" is taken by two broad plates, one on each side, which are known as the "jugular plates" or "gular plates."

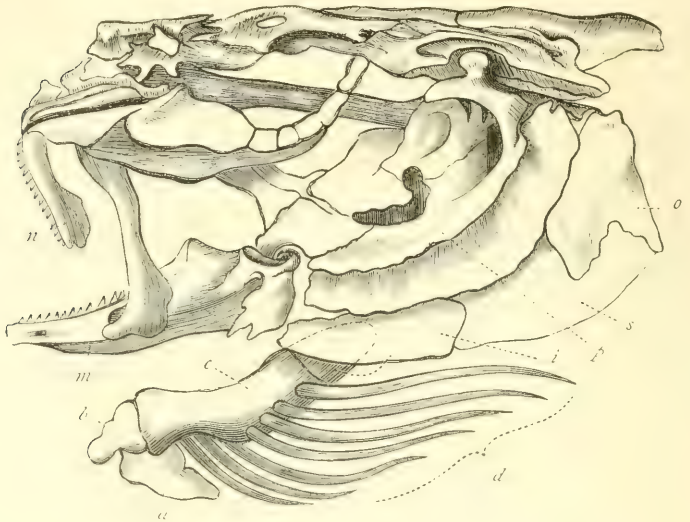

Fig. 488.—Skull of Cod (*Morrhua vulgaris*)—Cuvier. *a*, Urohyal; *b*, Basihyal; *c*, Ceratohyal; *d*, Branchiostegal rays; *p*, Pre-operculum; *o*, Operculum proper; *s*, Sub-operculum; *i*, Inter-operculum; *m*, Mandible; *n*, Intermaxillary bone.

The *limbs* of fishes depart considerably from the typical form exhibited in the higher Vertebrates. One or both pairs of limbs may be wanting, but when present the limbs are always in the form of *fins*—that is, of expansions of the integument strengthened by bony or cartilaginous fin-rays. The anterior limbs are known as the *pectoral* fins, and the posterior as the *ventral* fins; and they are at once distinguished from the so-called "median" fins by being always disposed in pairs, usually symmetrically. Hence they are often spoken of as the *paired* fins.

The fore-limbs or pectoral fins possess in a modified form most of the bones which are present in the anterior extremities of the higher *Vertebrata*. They vary much in size and in other characters. Sometimes they are enormously expanded, as in the Flying-fish (*Exocatus*); and at other times

they form merely a pair of paddles, as in the extinct *Pterichthys.*

The highest type of pectoral limb presented by any of the fishes, is that exhibited by *Ceratodus* (fig. 489), in which there is a median cartilaginous axis, formed by a succession of joints, which in turn support on each side a lateral series of jointed branches, these finally bearing the fin-rays. It seems certain that the "Crossopterygious" Ganoids of the Devonian and Carboniferous periods possessed a similarly-constructed pectoral fin.

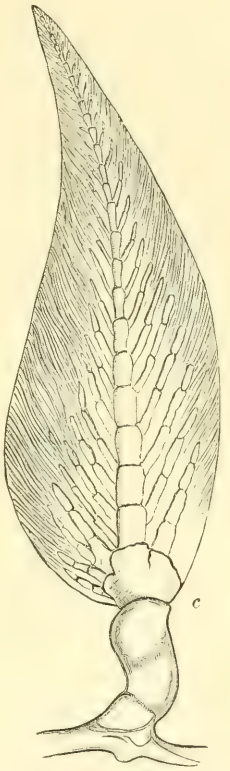

Fig. 489. — Skeleton of the pectoral fin of *Ceratodus*, showing the median axis and divergent branches on each side. *c*, Carpal cartilage. (After Günther.)

The hind-limbs or ventral fins are wanting in many fishes, and they are less developed and less fixed in position than are the pectorals. In some cases the ventral fins are "abdominal" in position, and are placed more or less towards the hinder part of the body (as in the Sharks, Ganoids, and Mud-fishes). In other cases, they are "thoracic"—that is, they are placed beneath the pectorals; and in some cases they are situated on the sides of the neck in advance of the pectorals, when they are said to be "jugular." In these cases the pelvic arch is attached to the pectoral arch, and is therefore wholly removed from its normal position.

In addition to the pectoral and ventral fins—the homologues of the limbs—which may be wanting, fishes are furnished with certain other expansions of the integument, which are "median" in position, and must on no account be confounded with the two "paired" fins. These median fins are variable in number, and in some cases there is but a single fringe running round the posterior extremity of the

body. In all cases, however, the median fins are "azygous"—that is to say, they occupy the middle line of the body, and are not symmetrically disposed in pairs. Most commonly, the median fins consist of one or two expansions of the dorsal integument, called the "dorsal fins" (fig. 490, *d*, *d'*); one or two on the ventral surface near the anus—the "anal fins" (fig. 490, *a*); and a broad fin at the extremity of the vertebral column, called the "caudal fin" or tail (*c*). In all cases, the rays which support the median fins are articulated with the so-called interspinous bones, which have been previously described. Though called "median," from their position in the middle line of the body, and from their being unpaired, the median fins of Fishes, as shown by Goodsir and Humphrey, are truly to be regarded as formed by the coalescence of two lateral elements in the mesial plane of the body.

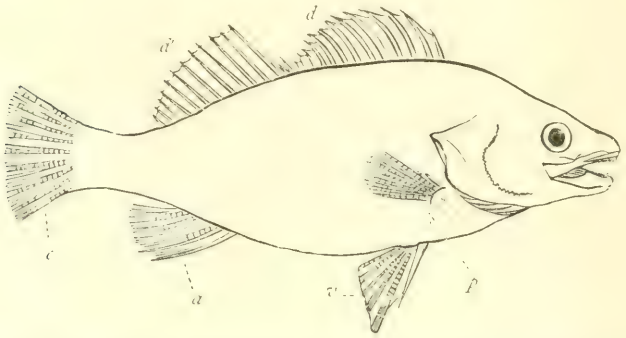

Fig. 490.—Outline of a fish (*Perca granulata*), showing the paired and unpaired fins. *p*, One of the pectoral fins; *v*, One of the ventral fins; *d*, First dorsal fin; *d'*, Second dorsal fin; *a*, Anal fin; *c*, Caudal fin.

The caudal fin, or tail, of fishes is always set vertically at the extremity of the spine, so as to work from side to side, and it is the chief organ of progression in the fishes. In its vertical position, and in the possession of fin-rays, it differs altogether from the horizontal integumentary expansion which constitutes the tail of the Whales, Dolphins, and *Sirenia* (Dugong and Manatee). In the form of the tail, fishes exhibit some striking differences. In some of the Bony fishes and Ganoids, the caudal extremity of the spine

is not bent upwards, but divides the caudal fin-rays into two nearly equal portions, and the symmetrical tail-fin thus produced is said to be "diphycercal." In the great majority of the Bony fishes the tail-fin appears on inspection to be divided into two equal lobes, and it is then said to be "homocercal" (fig. 491, A). This apparent symmetry is due to the fact that the spinal column seems to terminate in the centre of a triangular bony mass, to the free edges of which the fin-rays are symmetrically attached. In reality, however, the notochord is prolonged into the upper lobe of the tail; and as there is a much larger number of fin-rays below the bent-up notochord than above it, the tail is truly unsymmetrical in its fundamental structure. Lastly, in the *Elasmobranchii*, and most Ganoids, the tail is conspicuously unsymmetrical (fig. 491, B), and is then said to be "hetero-

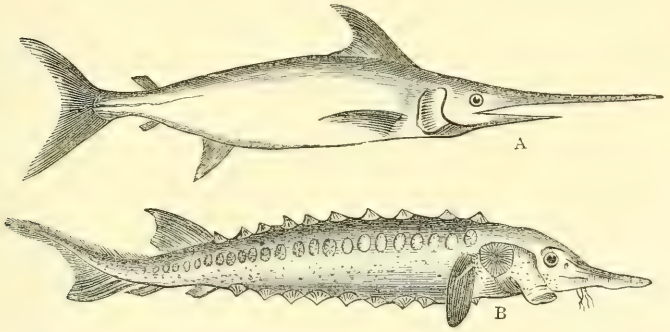

Fig. 491.—A, Sword-fish, showing homocercal tail; B, Sturgeon, showing the heterocercal form of tail.

cercal." In these cases, the lower lobe of the tail is conspicuously larger than the upper, owing to the disproportionate development of the hæmal spines, and the spinal column is prolonged into the upper lobe of the tail.

In a recently published and important memoir, Professor A. Agassiz has shown that in *Pleuronectes* and various other living Bony fishes, the tail of the early embryo is rounded, and is symmetrically developed at the hinder end of the straight notochord ("leptocardial stage"). Soon the chorda becomes arched upwards, and there appears the first trace of a separation of the tail-fin into two portions, only one of which is

destined to remain permanently. The superior of these two divisions, when both have become fully marked out, surrounds the end of the up-turned chorda (fig. 492, *a*), and it must be regarded as an embryonic structure, since it finally disappears. The inferior of the two divisions, on the other hand, is placed below the embryonic tail, and is ultimately

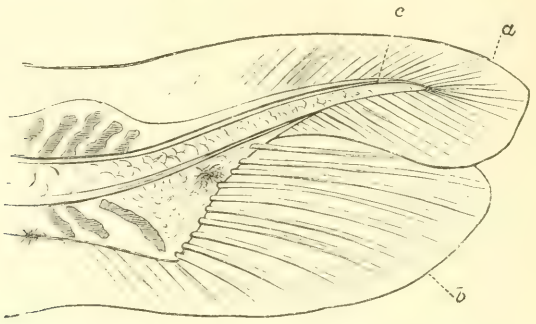

Fig. 492.—Tail of young Flounder (*Pleuronectes*) in its heterocercal stage of development. *a*, Embryonic caudal fin; *b*, Permanent caudal fin, occupying an inferior position; *c*, Bent-up end of the notochord. (After A. Agassiz.)

developed into the permanent tail. At first the permanent caudal fin has the appearance of a distinct lobe, which looks like a second anal fin. In process of growth, however, the embryonic caudal becomes thrown more and more upwards, and the rays of the permanent caudal acquire a fan-like arrangement. At the stage figured above (fig. 492), the tail is truly "heterocercal," and is wonderfully similar in appearance to the tail of many Palæozoic fishes. Finally, however, the turned-up end of the notochord becomes replaced by the long "urostyle;" the embryonic caudal diminishes in size and disappears; and the permanent caudal increases in size, and is gradually transformed from a ventral into a terminal appendage, the tail-fin thus assuming its ultimate "homocercal" constitution.

The above-mentioned facts have an important bearing upon certain palæontological theories. As is well known, Professor Louis Agassiz, one of the greatest of authorities upon all subjects relating to this class, maintained that the Palæozoic fishes in general were of an "embryonic" char-

acter. This theory was based essentially upon the fact that (1) the existing fishes have mostly "homocercal" tails when adult, but have "heterocercal" tails when in the embryonic condition; while (2) the Palæozoic and older Secondary fishes have almost invariably "heterocercal" tails when fully grown; and we do not meet with homocercal fishes till we reach the Jurassic period. Many arguments have been adduced against this theory, the most important being the fact, as shown by Huxley, that the so-called "homocercal" tail of the majority of existing fishes is only symmetrical by deceptive external appearance, and that it is in reality "heterocercal." On the other hand, the adult *Elasmobranchii* of the present day have heterocercal tails, whereas in their embryos the caudal fin is homocercal. The new observations of A. Agassiz would, however, go to show that the theory of the elder Agassiz is essentially correct. Thus it now appears that the really earliest stage of the tail in the Bony fishes and Elasmobranchs is the "leptocardial" stage, in which the tail is symmetrical and the notochord is straight, and that the "heterocercal" condition constitutes a second stage, superseded in the former by the permanent "homocercal" or "diphycercal" condition, but remaining throughout life in the latter group. Moreover, some of the ancient Devonian fishes have, as adults, a "leptocardial" tail; while others have a more or less marked "heterocercal" tail; but none of them reach the stage of a "homocercal" tail, such as that of the majority of living Bony fishes.

As regards their general *distribution in time*, the geological history of fishes presents some points of peculiar interest. Of all the classes of the great sub-kingdom *Vertebrata*, the fishes are the lowest in point of organisation. It might therefore have been reasonably expected that they would present us with the first indications of vertebrate life upon the globe; and such is indeed the case. After passing through the enormous group of deposits known as the Laurentian, Huronian, Cambrian, and Lower Silurian formations—representing an immense lapse of time during which, so far as we yet know for certain, no vertebrate animal had been created—we find in the Upper Silurian rocks the first

traces of undoubted fishes. The earliest of these, in Britain, is found in the base of the Ludlow rocks (Lower Ludlow Shale), and belongs to the placoganoid genus *Pteraspis*. Also in the Ludlow rocks, but at the summit of their upper division, are found fin-spines and shagreen, probably belonging to Cestraciont fishes—that is to say, to fishes of as high a grade of organisation as the *Elasmobranchii*. In the Upper Silurian of Europe various remains of fishes have likewise been found; but this formation in America has as yet yielded no fish-remains. So abundant are the remains of fishes in the next great geological epoch—namely, the Devonian or Old Red Sandstone—that this period has frequently been designated the "Age of Fishes." Most of the fishes of the Old Red Sandstone belong to the order *Ganoidei*, while the order *Dipnoi* is now represented for the first time. In the Carboniferous and Permian rocks, which close the Palæozoic period, most of the fishes are still Ganoid, but the former contain the remains of many Plagiostomous fishes. At the close of the Palæozoic and the commencement of the Mesozoic epoch, the Ganoid fishes begin to lose that predominant position which they before occupied, though they continue to be represented through the whole of the Mesozoic and Kainozoic periods up to the present day. The Ganoids, therefore, are an instance of a family which has endured through the greater part of geological time, but which early attained its maximum, and has been slowly dying out ever since. Towards the close of the Mesozoic period (in the Cretaceous period) the great order of the Teleostean or Bony fishes is for the first time known certainly to have made its appearance. The orders of the *Marsipobranchii* and *Pharyngobranchii* have not left, so far as is known, any traces of their existence in past time. Judging from analogy, however, it is highly probable that the two groups last mentioned must have had a vast antiquity, and in this connection we must briefly consider the extraordinary little fossils which are known as "Conodonts." These bodies were first discovered by Pander in the Silurian and Devonian of Russia, and numerous forms of them were described and figured by him in his great work on the fossil fishes of that

country. Since that time they have been found in the Silurian, Devonian, and Carboniferous formations of Britain and North America, and they have been stated to occur in later deposits (*e.g.*, Upper Trias). As regards their *size*, the

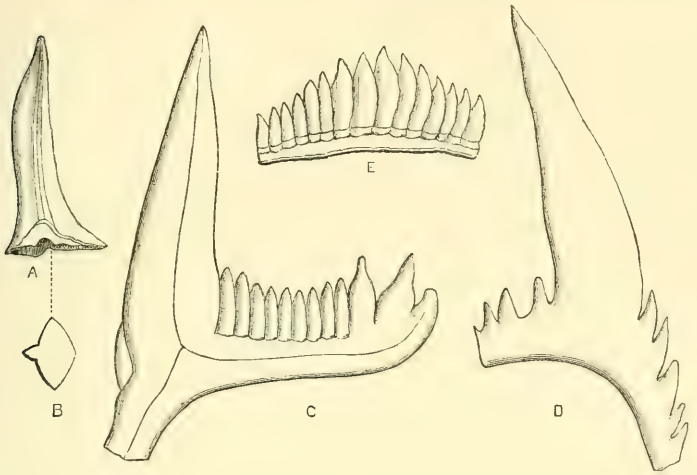

Fig. 493.—Outlines of some forms of "Conodonts," greatly enlarged. A, A simple form (*Acodus acutus*, Pander); B, Transverse section of the same; C and D, Two compound forms, from the Lower Silurian of Russia; E, Another compound form from the Carboniferous of North America. (After Pander and Newberry.)

"Conodonts" are always very small, the most of them, perhaps, between a thirtieth and a twentieth of an inch in length; though there are other bodies apparently of the same nature which sometimes reach a tenth or even a quarter of an inch in length. In their *form* they are extremely variable, though all the typical kinds have an exceedingly close resemblance to the teeth of different kinds of Fishes. The simplest forms are slender cones, usually more or less bent, hollow at the base, pointed at the end, with sharp opposite margins (fig. 493, A). Others (fig. 493, C) consist of a principal tooth, with a basal horizontal process bearing a row of small teeth. Others, again, have a central primary tooth, flanked by minor secondary cones on each side (fig. 493, D), thus reminding one forcibly of the teeth of *Hybodus*. Others (fig. 493, E) have an elongated base carrying a row of small cones on one side, the central

teeth being the largest. It is impossible, however, to give in this place any further exemplification of the great variety of form exhibited by these singular bodies. As regards their *texture*, the Conodonts have shining enamelled surfaces, and they appear to consist of a translucent horn-like material. In *microscopic structure* they are seen to consist of concentric layers of a minutely punctate tissue, which closely resembles the structure of the shell of many Crustaceans, though not absolutely incompatible with the theory that we may be dealing here with a peculiar form of dentinal tissue. Lastly, in *chemical composition*, they consist of carbonate of lime, with a notable proportion of phosphate of lime.

The above being the general characters of the "Conodonts," it remains briefly to consider what their true nature may be. By Pander, who first discovered them, and who gave a most careful and minute account of their peculiarities, they were regarded as being the teeth of Fishes, though he does not positively decide to what group of this class they should be referred. He compares them with the palatal teeth of certain Percoid fishes; and though he recognises their general likeness to the minute teeth of Cyclostomatous fishes, he rejects this view of their affinities upon the ground that they cannot be shown to possess the microscopic dentinal tubes which occur in these teeth. Owing to their great antiquity, much difficulty was felt by scientific men in accepting Pander's view that the "Conodonts" were the teeth of Fishes; and, after due examination, the high authority of Professor Owen was cast in favour of their belonging to Invertebrates, and having "most analogy with the spines, or hooklets, or denticles, of naked Molluscs and Annelides." On the other hand, Dr Harley, after examining microscopically a number of supposed "Conodonts" from the "Bone-bed" of the Ludlow formation (Upper Silurian), came to the conclusion that all these little bodies really belonged to Crustaceans, probably principally to Ceratiocaris. It is to be noticed, however, that almost all of the forms figured by this observer under the name of "Conodonts" have little or no likeness to the typical forms of these bodies as described and figured by Pander, and are probably not really "Cono-

donts" at all. Other views have been advanced by other authorities; but without entering into these further, it will be sufficient to note that Professor Newberry, one of our most distinguished authorities upon fossil fishes, after an examination of a large number of these bodies from the Carboniferous rocks of North America, has declared himself as inclined to the view that they are really the minute teeth of Cyclostomatous fishes allied to the living Lampreys and Hag-fishes. As these Fishes possess a cartilaginous skeleton and a scaleless skin, and have thus no other structures than their teeth which could possibly be preserved in a fossil state, there is no *a priori* improbability in this view. Indeed, the fact that fishes of as high rank as the *Ganoidei* and *Elasmobranchii* existed in the Upper Silurian, would render it quite probable that the much lower order of the *Marsipobranchii* had been developed in times as early as the Lower Silurian or Cambrian.

In the undecided state of this question, we cannot positively assert anything as to the past distribution of the *Marsipobranchii*. If the "Conodonts" should prove to be really the teeth of fishes like the Lampreys and Hags, then this order is the most ancient of all the groups of the Fishes, and must have been largely represented throughout the Palæozoic period. On this point, at present, we can only suspend our judgment. The still lower order of the *Pharyngobranchii*, including only the living Lancelet, may be safely dismissed from our consideration, as no structures capable of preservation in the fossil state are developed in this order, and we can therefore never know anything as to its past history. There remain, therefore, for consideration only the orders of the *Teleostei* (Bony fishes), *Ganoidei* (Ganoids), *Elasmobranchii* (Sharks and Rays), and *Dipnoi* (Mud-fishes).

CHAPTER XXXI.

ORDERS OF FISHES.

Order I. Teleostei.—This order includes the great majority of fishes in which there is a well-ossified endoskeleton, and it corresponds very nearly with Cuvier's division of the "osseous" fishes. The *Teleostei* are defined as follows: *The skeleton is usually well ossified; the cranium is provided with cranial bones, and a mandible is present; whilst the vertebral column almost always consists of more or less completely ossified vertebræ. The pectoral arch has a clavicle; and the two pairs of limbs, when present, are in the form of fins supported by rays. The gills are free, pectinated or tufted in shape, a bony gill-cover and branchiostegal rays being always developed. The branchial artery has its base developed into a bulbus arteriosus; but this is never rhythmically contractile, and is separated from the ventricle by no more than a single row of valves.*

The scales in the Teleostean fishes are generally thin, horny, flexible plates, which overlap one another, and have the "cycloid" or "ctenoid" characters. The order, therefore, corresponds in a general way with the orders *Ctenoidei* and *Cycloidei* of Agassiz. Some of the Teleostean fishes, however, are provided with *ganoid* scales.

Excluding the *Leptolepidæ*, which are sometimes referred to this order, the *Teleostei* do not seem to have any representatives in times anterior to the Cretaceous period—that is, towards the close of the Mesozoic period. From this time on, however, Bony fishes with cycloid or ctenoid

scales are the chief fossil representatives of the whole class of the fishes, and the order appears to have attained its maximum at the present day.

The order *Teleostei* is divided into the following sub-orders :—

Sub-order A. Malacopteri, Owen (= *Physostomata*, Müller).—This sub-order is defined by usually possessing a complete set of fins, supported by rays, all of which are "*soft*" or many-jointed, with the occasional exception of the first rays in the dorsal and pectoral fins. A swim-bladder is always present, and always communicates with the œsophagus by means of a duct, which is the homologue of the windpipe. The skin is rarely naked, and is mostly furnished with cycloid scales; but in some cases ganoid plates are present.

The more important families comprised in this sub-order are the *Muræniдæ* (Eels), the *Clupeidæ* (Herrings), the Pikes (*Esocidæ*), the Sheat-fishes (*Siluridæ*), the *Cyprinidæ* (Carp, Chub, Barbel, &c.), and the *Salmonidæ* (Salmon and Trout). None of these families attain any great development prior to the Tertiary period, though several of them appear in the Cretaceous. Thus the genus *Osmeroides* (fig. 494) includes Cretaceous representatives of the *Salmonidæ;*

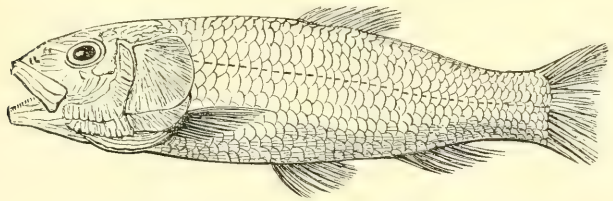

Fig. 494.—*Osmeroides Mantelli*, a Salmonoid fish from the Chalk.

the genus *Pelecorapis*, of the same formation, may be allied to the living *Exocœtus;* and we may perhaps place in the neighbourhood of the Pikes (*Esocidæ*) the Cretaceous genera *Enchodus*, *Stratodus*, *Pachyrhizodus*, &c. The Clupeoids seem also to be represented by allied forms at this comparatively early period; but the *Cyprinidæ* and *Muræniдæ* do not appear till the Tertiary period is reached. From a palæon-

tological point of view, however, the most important group of the *Malacopteri* is that of the Sheat-fishes (*Siluridæ*). The importance of this group does not arise from the occurrence of many fossil fishes which can be definitely referred to it, but from its relationship, on the one hand, to the "Saurodont" fishes of the Cretaceous, and, on the other hand, to the much more ancient group of the "Placoderms" of the Silurian and Devonian. The living forms are chiefly noticeable because they are amongst the small number of living fishes possessed of structures of the same nature as the fossil spines known as "ichthyodorulites." The structure in question consists of the first ray of the pectoral fins, which is largely developed and constitutes a formidable spine, which the animal can erect and depress at pleasure. Unlike the old "ichthyodorulites," however, the spines of the *Siluridæ* have their bases modified for articulation with another bone, and they are not simply hollow and implanted in the flesh. The head is protected by an exoskeleton of dermal bones, thus coming to resemble structures with which the palæontologist is familiar in the head-shields of the extraordinary *Pteraspis*, *Pterichthys*, *Coccosteus*, and other Palæozoic Placoderms. The latter appear, however, to be truly Ganoids; but we may more safely place in the neighbourhood of the "Siluroids" the large and important Cretaceous family of the

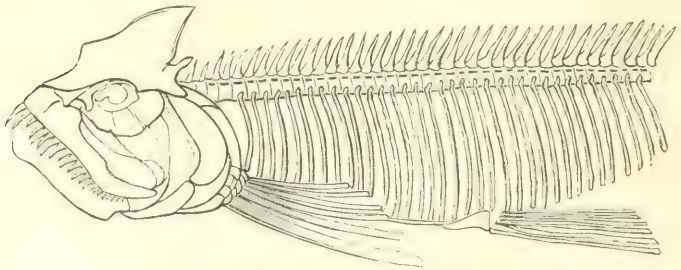

Fig. 495.—Skull and fore-part of the skeleton of *Portheus*, restored (after Cope). Cretaceous.

"Saurodont" fishes, typified by such genera as *Portheus* (fig. 495), *Ichthyodectes*, *Daptinus*, *Hypsodon*, *Saurocephalus*, and various allied forms. The fishes of this group were all car-

nivorous in their habits, and often attained a very large size, and they have been detected in comparatively large numbers on the same geological horizon both in Europe and North America. In this family the first ray of the pectoral fins forms a formidable defensive weapon; but the most striking character is found in the greatly-developed and powerful teeth, which may be equal or unequal in size, and are sometimes cylindrical, sometimes compressed and lancet-shaped.

Sub-order B. Anacanthini.—This sub-order is distinguished by the fact that the fins are entirely supported by "soft" rays, and never possess "spiny" rays; whilst the ventral fins are either wanting, or, if present, are placed under the throat, beneath or in advance of the pectorals, and supported by the pectoral arch. The swim-bladder may be wanting, but when present it does not communicate with the œsophagus by a duct.

The only important families in this sub-order are the *Gadidæ* (Cod family) and the *Pleuronectidæ* (Flat-fishes). The *Gadidæ* comprise the living Cod, Haddock, Whiting, &c., and appear to date their existence from the Eocene Tertiary. The *Pleuronectidæ* comprise the living Sole, Flounder, Plaice, and the like, in which the body is very much compressed from side to side, and is bordered by long dorsal and anal fins. The bones of the head are twisted in such a manner that both eyes are brought to one side of the body. The fish keeps this side uppermost, and is dark-coloured on this aspect; whilst the opposite side, on which it rests, is white. The mouth has the two sides unequal, the pectorals are rarely of the same size, the ventrals look like a continuation of the anal fin, and the branchiostegal rays are six in number. The *Pleuronectidæ* are only known by two or three fossils, of which the oldest is the little *Rhombus minimus* (fig. 496) of the Eocene deposits of Monte Bolca.

Sub-order C. Acanthopteri.—This sub-order is characterised by the fact that one or more of the first rays in the fins are in the form of true, unjointed, inflexible, "spiny" rays. The exoskeleton consists, as a rule, of

ctenoid scales. The ventral fins are generally beneath or in advance of the pectorals, and the duct of the swim-bladder is invariably obliterated.

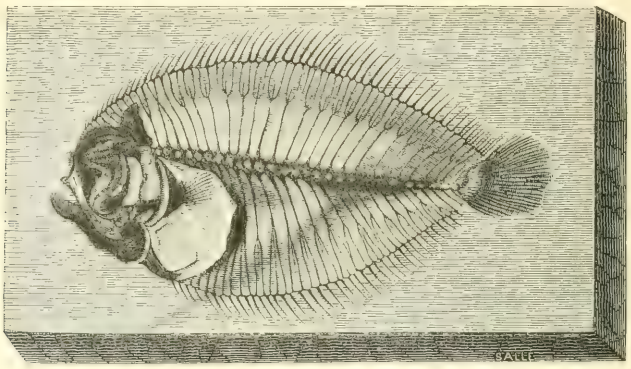

Fig. 496.—*Rhombus minimus.* A small fossil Turbot from the Eocene Tertiary of Monte Bolca.

The chief living families of this sub-order are the Perch family (*Percidæ*), the Mullets (*Mugilidæ*), the Mackerel family (*Scombridæ*), the Gurnards (*Sclerogenidæ*), the Blennies (*Blenniidæ*), the Gobies (*Gobiidæ*), and the Chætodons (*Chætodontidæ*). The fossil representatives of this sub-order are mainly Tertiary; but the genus *Beryx* (fig. 497) dates

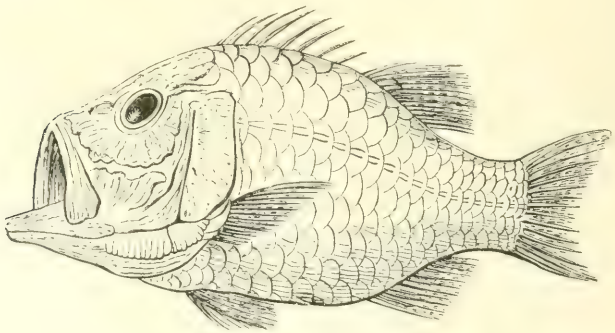

Fig. 497.—*Beryx Lewesiensis.* A Percoid fish from the Chalk.

from the Cretaceous period. The Cretaceous *Syllæmus* is also probably an ancient representative of the Mullets. In the Eocene Tertiary of Monte Bolca occur several remark-

able forms, of which one of the most singular is the Chætodont genus *Platax* (fig. 498).

Sub-order D. Plectognathi.—This sub-order is characterised by the fact that the maxillary and premaxillary bones

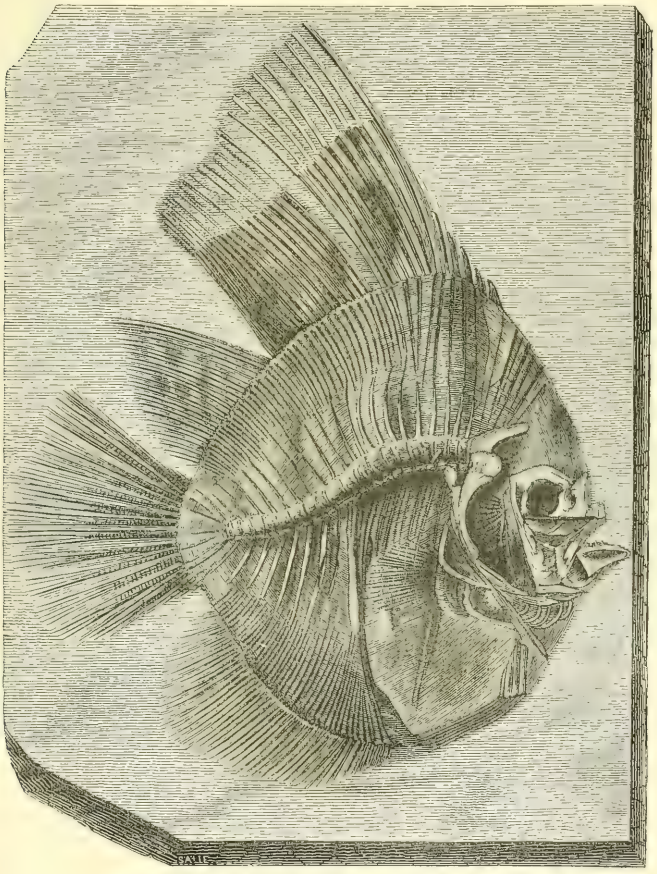

Fig. 498.—*Platax altissimus*. A Chætodont from the Eocene Tertiary of Monte Bolca.

are immovably connected on each side of the jaw. The endoskeleton is only partially ossified, and the vertebral column often remains permanently cartilaginous. The exoskeleton is in the form of ganoid plates, scales, or spines.

The ventral fins are generally wanting, and the air-bladder is destitute of a duct.

This sub-order includes the living Trunk-fishes (*Ostraciontidæ*), File-fishes (*Balistidæ*), and Globe-fishes (*Gymnodontidæ*). The fossil forms are few in number, and the earliest date from the Eocene Tertiary. They are chiefly noticeable for the resemblance to the true Ganoid fishes, produced by their partially ossified endoskeleton and by their possession of *ganoid* scales.

Sub-order E. Lophobranchii.—This is a small and unimportant group, mainly characterised by the peculiar structure of the gills, which are arranged in little tufts upon the branchial arches, instead of forming comb-like plates, as in the typical Bony fishes. The endoskeleton is only partially converted into bone, and the exoskeleton, by way of compensation, consists of ganoid plates. The swim-bladder is destitute of an air-duct.

This sub-order comprises the living Pipe-fishes (*Syngnathidæ*) and Sea-horses (*Hippocampidæ*). A few fossil forms are known, dating from the Eocene Tertiary.

Order II. Ganoidei. — The order of the Ganoid fishes may be defined by the following characters: *The endoskeleton is only partially ossified, the vertebral column mostly remaining cartilaginous throughout life, especially amongst the extinct forms of the Palæozoic period, in which the notochord is often persistent. The skull is furnished with distinct cranial bones, and the lower jaw is present. The exoskeleton is in the form of ganoid scales, plates, or spines. There are usually two pairs of limbs, in the form of fins, each supported by fin-rays. The first rays of the fins are mostly in the form of strong spines. The pectoral arch has a clavicle, and the posterior limbs (ventral fins) are placed close to the anus. The caudal fin is mostly unsymmetrical or "heterocercal," but is sometimes "homocercal." The swim-bladder is always present, is often cellular, and is provided with an air-duct. The intestine is often furnished with a spiral valve. The gills and opercular apparatus are essentially the same as in the Bony fishes. The heart has one auricle and a ventricle, and the base of the branchial artery is dilated into a bulbus arteriosus, which is rhythmically contrac-*

tile, is furnished with a distinct coat of striated muscular fibres, and is provided with several transverse rows of valves.

Of these characters, those which it is most important to remember are the following:—

1. The *endoskeleton* is rarely thoroughly ossified, but varies a good deal as to the extent to which ossification is carried. In some forms, including most of the older members of the order, the chorda dorsalis is persistent, no vertebral centra are developed, and the skull is cartilaginous, and is protected by ganoid plates. Even in these forms, however, the peripheral elements of the vertebræ may be ossified. In others, the bodies of the vertebræ are marked out by osseous or semi-cartilaginous rings, enclosing the primitive matter of the notochord. In others, the vertebræ are like those of the Bony fishes—that is to say, deeply biconcave or "amphicœlous." In one Ganoid, however—the Bony Pike (*Lepidosteus*)—the vertebral column consists of a series of "opisthocœlous" vertebræ—that is to say, vertebræ which are convex in front and concave behind. This is the highest point of development reached in the spinal column of any fish, and its structure is more Reptilian than Piscine.

2. The *exoskeleton* consists, in all Ganoid fishes in which it is present, of scales, plates, or spines, which are said to possess *ganoid* characters. The peculiarities of these scales are that they are composed of two distinct layers—an inferior layer of bone and a superficial covering of a kind of enamel, somewhat similar to the enamel of the teeth, called "ganoine." In form the ganoid scales most generally exhibit themselves as rhomboidal plates, placed edge to edge, without overlapping, in oblique rows (fig. 499), the plates of each row being often articulated to those of the next by distinct processes. In other cases the ganoid structures are simply in the form of detached plates, tubercles, or spines; and in some cases their *shape* is undistinguishable from the horny scales of the typical Teleostean fishes, being circular and overlapping. It is to be remembered, however, that these *ganoid* plates and scales are not confined to the fishes of the order *Ganoidei*, but that they occur in two sub-orders of the Bony fishes —namely, the *Plectognathi* and *Lophobranchii*—and in some

others of the *Teleostei* as well. Moreover, some of the Ganoids (*Spatularia*) have the skin quite naked; while

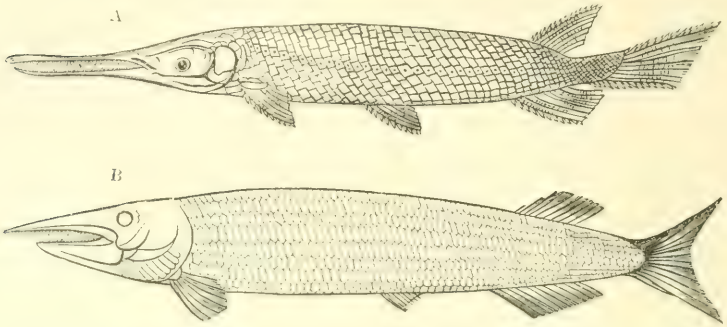

Fig. 499.—A, *Lepidosteus osseus*, the "Gar-pike" of the American lakes; B, *Aspidorhynchus*, restored (after Agassiz), a Jurassic Ganoid allied to *Lepidosteus*, but having a homocercal tail.

others (*Acipenser* and *Scaphirhynchus*) have detached dermal plates of true bone.

3. As to the *fins*, both pectorals and ventrals are usually present, and the ventrals are always placed far back, in the neighbourhood of the anus, and are never situated in the immediate vicinity of the pectorals. In some living and many

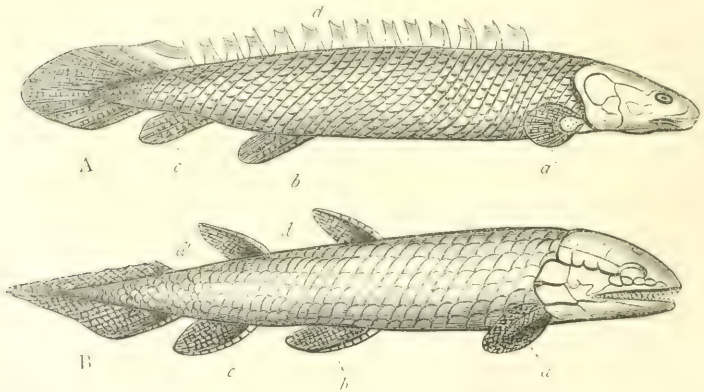

Fig. 500.—Ganoid Fishes. A, *Polypterus* (recent); B, *Osteolepis* (extinct). *a*, One of the pectoral fins, showing the fin-rays arranged round a central lobe; *b*, One of the ventral fins; *c*, Anal fin; *d*, Dorsal fin; *d'*, Second dorsal fin.

extinct forms the fin-rays of the paired fins are arranged so as to form a fringe round a central lobe (fig. 500). This

structure characterises a division of Ganoids called by Huxley, for this reason, *Crossopterygidæ*, or "fringe-finned." The form of the caudal fin varies, the Ganoids being in this respect intermediate between the Bony fishes, in which the tail is "homocercal," and the Sharks and Rays, in which there is a "heterocercal" caudal fin. In the majority of Ganoids, then, the tail is unsymmetrical or "heterocercal," but it is sometimes equi-lobed or "homocercal."

The living genera of Ganoids are exclusively or mainly inhabitants of fresh waters; but many of the extinct forms occur in association with marine animals, and must therefore be assumed to have inhabited the sea. Others, again, are found in undoubted lacustrine deposits; and lastly, there are others which are found in beds where there are no other fossils which can be certainly asserted to have lived either in fresh or salt water; and as to the mode of life of these we must at present remain in doubt.

As regards their general *distribution in time*, the oldest representatives of the fishes belong, so far as is yet known with certainty, to this order. The order, namely, is represented in the Upper Silurian rocks of Bohemia and Britain by several Ganoid fishes, which have been referred to five distinct genera. In the Devonian rocks, or Old Red Sandstone, the Ganoids attain their maximum. The singular family of the *Cephalaspidæ* appears to die out finally at the close of this period, and the great group of the *Crossopterygidæ* attained here its highest development, being represented at the present day by the single genus *Polypterus*. The Carboniferous and Permian rocks contain an abundance of Lepidoganoids. In the Mesozoic period, the Lepidoganoids are very largely represented by various extinct types, many of which belong to the family of the *Lepidosteidæ*—represented at the present day by the Bony Pike or Gar-pike of North America. Here, also, we have for the first time representatives of the family of the *Chondrosteidæ*, to which the living Sturgeons belong. Lastly, in the Oolitic rocks appear for the first time Lepidoganoids with homocercal tails, and they continue to be represented up to the present day. In the Tertiary rocks true Sturgeons (*Acipenser*) make their

appearance; but the Ganoids are now considerably outnumbered by the Teleostean fishes; and the latter have a still more marked predominance at the present day.

The *classification* of the Ganoid fishes has hitherto proved a matter of considerable difficulty; and probably no arrangement that has been as yet proposed can be regarded as being, in all its details, more than provisional. A convenient primary division is that into *Lepidoganoids*, in which the body is furnished with scales of moderate size, and the endoskeleton is generally more or less perfectly ossified; and *Placoganoids*, in which the skeleton is imperfectly ossified, and the head and more or less of the body are protected by large ganoid plates, which in many cases are united together by sutures. Accepting this division, the order *Ganoidei* may be divided into the following sub-orders:—

Section 1.—Lepidoganoidei.

Sub-order A. *Amiadæ*.
„ B. *Lepidosteidæ*.
„ C. *Platysomidæ*.
„ D. *Crossopterygidæ*.
„ E. *Acanthodidæ*.

Section 2.—Placoganoidei.

Sub-order F. *Ostracostei*.
„ G. *Chondrosteidæ*.

The position of at least two of these sub-orders (viz., *Acanthodidæ* and *Ostracostei*) in the order of the Ganoids is questionable. In any case, the number of forms included in these sub-orders is so large that nothing more can be done here than simply to draw attention to some of the more striking examples of each.

Sub-order A. Amiadæ.—In this sub-order are included Ganoids in which the scales are rounded and overlap one another, and the tail is slightly heterocercal. The vertebral column is ossified, and the external appearance approaches closely to that of an ordinary Teleostean fish. A præ-operculum is present, with branchiostegal rays, a median jugular plate, and non-lobate paired fins. This division is repre-

sented at the present day by the Trout-like "Dog-fishes" (*Amia*) of the North American lakes; and forms only specifically separable from the recent ones occur in the Tertiary formations of the same country. No pre-Tertiary examples of the group are as yet known; though it is by no means impossible that some Mesozoic forms may ultimately prove to be Amioids.

Sub-order B. Lepidosteidæ. — Scales rhomboidal, not overlapping; tail heterocercal, sometimes homocercal; paired fins not lobate; fin-borders generally with fulcral scales; branchiostegal rays not modified to form "jugular plates." This sub-order is represented at the present day by the Gar-pike (*Lepidosteus*, fig. 499, A) of the North American continent, and it attained its greatest development in the Mesozoic period. The exact range of the sub-order in time is uncertain, as it has not yet been determined what forms should be included in it. The oldest known type is the *Cheirolepis* of the Devonian, which has been shown by Dr Traquair to be allied to *Palæoniscus*. In the Carboniferous and Permian rocks the sub-order is mainly represented by the genera *Palæoniscus* and *Amblypterus* (fig. 501), in which

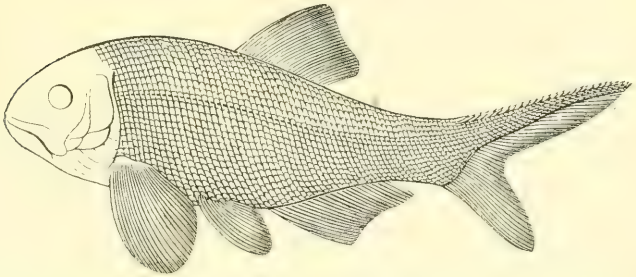

Fig. 501.—*Rhabdolepis* (*Amblypterus*) *macropterus*. Lower Permian. (After Agassiz.)

the tail is heterocercal, and the jaws are furnished with numerous minute teeth. Numerous species of these genera are known in the above-mentioned formations, and both appear for the last time in the Trias. Belonging to the same family as the preceding (*Palæoniscidæ*) are various genera from the Upper Palæozoic rocks, such as *Pygopterus*,

Nematoptychius, *Gonatodus*, *Cycloptychius*, &c.[1] In the Secondary rocks *Lepidosteoids* are extremely abundant, the chief forms belonging to the families *Dapediidæ*, *Lepidotidæ*, and *Leptolepidæ*. In the *Dapediidæ* (fig. 502, 1), the tail-fin is only slightly heterocercal, the scales are interlocked by pegs and sockets, and the back teeth are obtuse. *Dapedius*

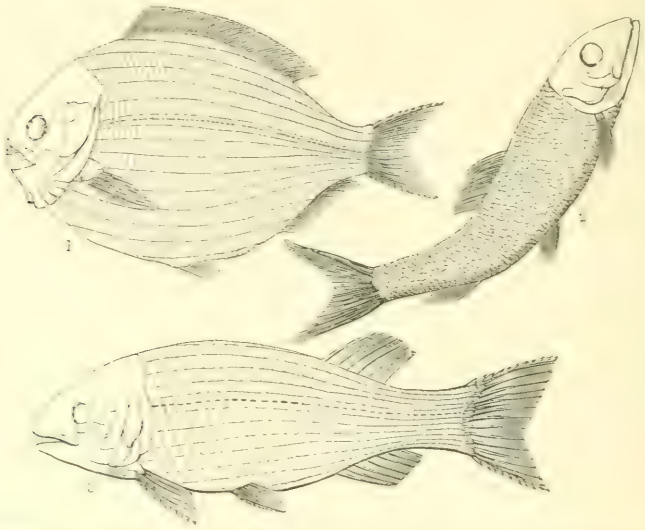

Fig. 502.—1, *Dapedius tetragonolepis*; 2, *Leptolepis sprattiformis*; 3, *Lepidotus Valdensis*.

itself is compressed and deep-bodied, and is exclusively confined to the Lias. The front teeth in this genus are typically notched or bifurcate. The Jurassic *Æchmodus* (fig. 503) has been separated from *Dapedius* upon the ground that the teeth have unicuspidate crowns; but this alleged distinction has been shown to be neither constant nor reliable, and the former name must therefore be abandoned. The Jurassic genus *Tetragonolepis* is closely allied to *Dapedius*, especially in its greatly compressed body and its single long dorsal fin; but, as shown by Quenstedt

[1] Contrary to the views which have usually been held by ichthyologists, Dr Traquair has expressed the opinion that the *Palæoniscidæ* (as also the *Platysomidæ*) are more nearly allied to the Acipenseroids than to the *Lepidosteidæ*.

and Sir Philip Egerton, the articulation of the scales, instead of being by pegs and sockets, as in *Dapedius*, rather resembles that of the "Pycnodonts," to which the genus is very closely allied. Each scale, namely, bears upon its inner anterior margin a thick, solid, bony rib, extending

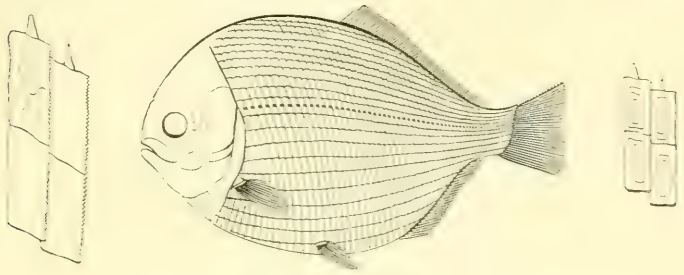

Fig. 503.—*Dapedius* (*Æchmodus*), restored. Lias.

upwards beyond the margin of the scale, and sliced off obliquely above and below, on opposite sides, for forming splices with the corresponding processes of adjoining scales. The *Lepidotidæ* have a homocercal tail (fig. 502, 3), and possess obtuse teeth. The type-genus, *Lepidotus*, ranges from the Lias to the Eocene Tertiary. The *Leptolepidæ* (fig. 502, 2) have also a homocercal tail, and possess small rounded scales. The species of this family are all Secondary in their distribution.

According to the researches of Traquair, the well-known group of Secondary fishes comprised under the name of *Pycnodontidæ*, should really be placed under the Lepidosteids, rather than with the *Platysomidæ*, as has usually been done. In this group the body is rhomboidal and compressed, and covered with rhombic scales, while the teeth are characteristically blunt and rounded. In the true Pycnodonts the teeth (fig. 504) are multiserial, and are adapted for crushing; consisting of "a circular or transversely oval crown, flattened above, and sessile on the bone to which it is attached; or of an obtusely conical crown, which is broader than its peduncle of support" (Young). There are typically five rows of teeth on the vomer, while the lower jaw carries a corresponding series of three, four, or five rows of dental

plates. The Pycnodonts (*Pycnodus, Gyrodus, Cœlodus, Mesodon,* &c.) are principally Jurassic; but there are various Cretaceous forms, and a few Eocene and Miocene types are

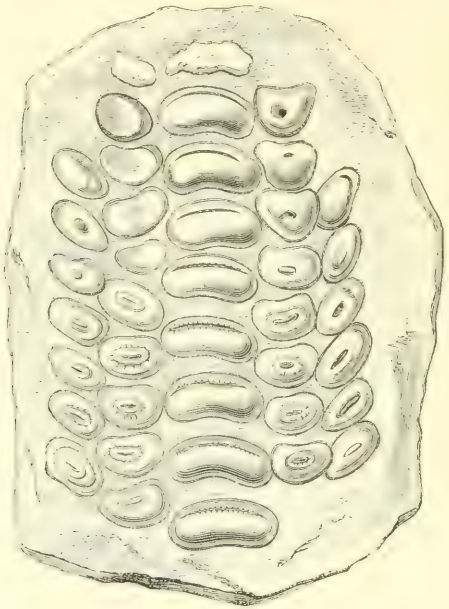

Fig. 504.—Under surface of the vomer of *Cœlodus gyrodoides*, showing the rows of crushing teeth. Cretaceous. (After Sir Philip Egerton.)

known. The Triassic *Placodus*, formerly referred to this family, is now known to be truly Reptilian.

Sub-order C. Platysomidæ.[1] — The fishes included in this division are mainly Carboniferous and Permian, and have a close general resemblance to the Pycnodonts. The body is deep and compressed; and the scales are rhom-

[1] The separation of the *Pycnodonts* and *Platysomidæ*, and the elevation of the latter to the rank of a distinct division of Ganoids are in accordance with the views of Dr Traquair, our greatest authority upon the subject of the fossil fishes. In this connection the author has to return his best thanks to Dr Traquair for the permission to make use of his researches on this subject, which will shortly appear in the 'Transactions of the Royal Society of Edinburgh,' but which are as yet unpublished. The author has also to gratefully acknowledge much other friendly assistance as regards the fossil fishes from the same source.

boidal, and are articulated to one another by processes developed on the internal surface of their anterior margins. In the genus *Platysomus* (fig. 505) the tail is heterocercal, the dorsal and anal fins are long, the pectorals are small, and the ventrals appear to be wanting. The teeth are conical and uniserial, and the body is deep and compressed

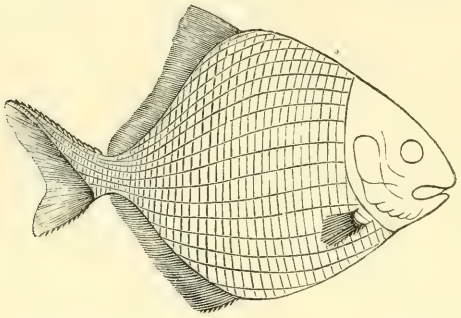

Fig. 505.—*Platysomus gibbosus.* Middle Permian.

from side to side. The *Platysomi* are mainly found in the Permian rocks. Another genus of this family is the Carboniferous *Cheirodus* of M'Coy (= *Amphicentrum*), in which the body is deep and rhombic; the scales are high and narrow; and the front of the jaws is edentulous, while the palate and hinder portion of the mandible are furnished with ridges carrying "small tubercular tooth-like elevations" (Traquair). The other genera included by Traquair in the family of the *Platysomidæ* are *Eurynotus, Benedenius, Mesolepis, Eurynomus,* and *Wardichthys.*

Sub-order D. Crossopterygidæ.—"Dorsal fins two, or, if single, multifid or very long; the pectoral, and usually the ventral, fins lobate; no branchiostegal rays, but two principal, with sometimes lateral and median, jugular plates, situated between the rami of the mandible; caudal fin diphycercal, or heterocercal; scales cycloid or rhomboid, smooth or sculptured."—(Huxley.)

All the Ganoids of this sub-order are pre-eminently distinguished by the structure of the paired fins, the pectorals always, and the ventrals usually, consisting of a central lobe

or stem, which is covered by scales, and to the sides of which the fin-rays are attached. The nearest approach to this structure amongst living fishes is found in the paired fins of the Barramunda (*Ceratodus Forsteri*) of the rivers of Queensland. In this singular fish, which is referable to the order of the *Dipnoi*, the pectoral and ventral fins are supported by a median, many-jointed, cartilaginous rod, to which numerous lateral branches are attached (fig. 489). The scales in this sub-order are sometimes rhomboidal, not overlapping one another; at other times they are cycloidal in shape, and are arranged in an imbricate manner.

Professor Huxley, in his classical memoir upon the Fossil Ganoids, divides the *Crossopterygidæ* into the following families (*see* 'Memoirs of the Geological Survey of Great Britain. Decade X.'):—

Fam. 1.—Polypterini.
Dorsal fin very long, multifid; scales rhomboidal.
Polypterus (fig. 500).

Fam. 2.—Saurodipterini.
Dorsal fins two; scales rhomboidal, smooth; fins sub-acutely lobate.
Diplopterus, *Osteolepis* (fig. 500), *Megalichthys*.

Fam. 3.—Glyptodipterini.
Dorsal fins two; scales rhomboidal or cycloidal, sculptured; pectoral fins acutely lobate; dentition dendrodont.
Sub-fam. A. with rhomboidal scales.
Glyptolæmus (fig. 506), *Glyptopomus*, *Gyroptychius*.
Sub-fam. B. with cycloidal scales.
Holoptychius (fig. 507), *Glyptolepis*, *Platygnathus* [*Rhizodus*, *Dendrodus*, *Cricodus*, *Lamnodus*].

Fam. 4.—Ctenodipterini.
Dorsal fins two; scales cycloidal; pectorals and ventrals acutely lobate; dentition ctenodont.
Dipterus [*Ceratodus ? Tristichopterus ?*]

Fam. 5.—Phaneropleurini.
Dorsal fin single, very long, not subdivided, supported by many interspinous bones; scales thin, cycloidal; teeth conical, ventral fins very long, acutely lobate.
Phaneropleuron (fig. 510).

Fam. 6.—Cœlacanthini.

Dorsal fins two, each supported by a single interspinous bone; scales cycloidal; paired fins obtusely lobate; air-bladder ossified. *Cœlacanthus, Undina, Macropoma.*

As regards the above arrangement of the *Crossopterygidæ*, the chief change which has been effected by recent researches relates to the group of the *Ctenodipterini*. Thus, it has been shown that *Ceratodus* and *Dipterus* are not only closely allied to one another, but that the former is related to *Lepidosiren* by characters which appear to have an ordinal value. *Tristichopterus*, on the other hand, has been shown by Traquair to belong to the cycliferous division of the *Glyptodipterini*. The result of this is that the group of the *Ctenodipterini* must be removed from association with the Crossopterygious Ganoids, and must stand in future as a section of the order *Dipnoi*. The only alternative step is to reduce the *Dipnoi* from the rank of an order to that of a mere section of the *Ganoidei*. The present condition of our knowledge of this subject will probably be best expressed if we subjoin here the following table, showing the classification of the *Crossopterygidæ* proposed by Dr Traquair (Trans. Roy. Soc. Edin., vol. xxvii.):—

Section I.—Caudal diphycercal, but with shortened body-axis. Dorsal fin multifid, pectorals obtusely lobate, scales rhomboidal.

Fam. 1.—Polypteridæ (*Polypterus, Calamoichthys*).

Section II.—Caudal with elongated attenuated body-axis, heterocercal or diphycercal.

A. Pectorals obtusely lobate, tail diphycercal, dorsal fins two, scales cycloidal, air-bladder ossified.

Fam. 2.—Cœlacanthidæ (*Cœlacanthus, Macropoma, Holophagus*).

B. Pectorals sub-acutely lobate, dorsal fins two, tail heterocercal or diphycercal.

a. Scales rhomboidal.

Fam. 3.—Rhombodipteridæ.

* Scales sculptured.

Sub-fam.—Glyptolæmini (*Glyptolæmus, Glyptopomus*).

** Scales smooth.

Sub-fam.—Saurodipterini (*Osteolepis, Diplopterus, Megalichthys*).

b. Scales cycloidal, sculptured.

Fam. 4. — Cyclodipteridæ (*Tristichopterus, Gyroptychius* (?), *Rhizodus, Rhizodopsis, Strepsodus, Archichthys* (?)).

C. Pectorals acutely lobate, scales cycloidal.

a. Dorsal fins two, ventrals sub-acutely lobate, scales thick, sculptured.

Fam. 5.—Holoptychiidæ (*Holoptychius, Glyptolepis, Dendrodus* (?), *Cricodus* (?)).

b. Dorsal fin elongated, continuous with the upper part of the caudal; ventral fins acutely lobate; scales thin.

Fam. 6.—Phaneropleuridæ (*Phaneropleuron, Uronemus*).

As regards the distribution of the *Crossopterygidæ* in time, Professor Huxley remarks: "Of the six families which compose it, four are not only Palæozoic, but are, some exclusively, and all chiefly, confined to rocks of Devonian age —an epoch in which, so far as our present knowledge goes, no fish belonging to the sub-orders of the *Amiadæ* and *Lepidosteidæ* (unless *Cheirolepis* be one of the latter) makes its appearance. Rapidly diminishing in number, the Crossopterygidæ seem to have had several representatives in the Carboniferous epoch; but after this period (unless *Ceratodus* be a *Ctenodipterine*) they are continued through the Mesozoic age only by a thin, though continuous, line of Cœlacanthini, and terminate, at the present day, in the two or three known species of the single genus *Polypterus*."

Of the extinct types of this sub-order, some are sufficiently important to merit especial mention. In the family of the *Saurodipterini*, the genus *Osteolepis* (fig. 500) has a very heterocercal tail and smooth scales. The first dorsal is placed near the centre of the back, and the mouth is furnished with sharp teeth. All the species of this genus are Devonian. The Carboniferous genus *Megalichthys* appears also to belong here. In this singular genus are large "sauroid" fishes with heterocercal tails, rhomboidal scales, and great conical incurved teeth, which are mostly smooth, but are sometimes finely ridged.

Of the *Glyptodipterini* with rhomboidal scales, *Glyptolæmus* (fig. 506) may be taken as the type. In this singular fish, the body is elongated and the head depressed. There are two dorsal fins which are placed very far back, and the ventrals have a similar posterior position. The tail is "divided into two equal lobes by the prolonged conical termination of the body," becoming thus "diphycercal." *Glyptolæmus* is exclusively confined to the Devonian period.

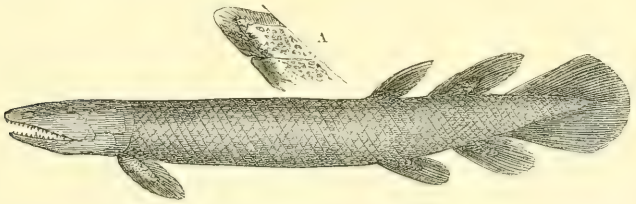

Fig. 506.—*Glyptolæmus Kinnairdi.* Restored. A, Scale of the same. Devonian.

Of the *Glyptodipterines* with cycloidal scales, the most important form is *Holoptychius* (fig. 507). In this genus there are two dorsal fins placed very far back, and the ven-

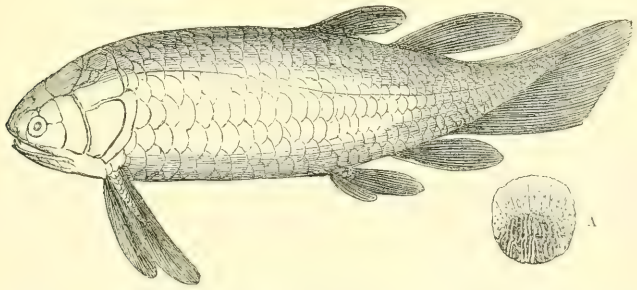

Fig. 507.—*Holoptychius nobilissimus.* Restored. A, Scale of the same. Devonian.

trals are similarly approximated to the tail, as in *Glyptolæmus*; while the pectorals are similarly *acutely* lobate. The body, however, is covered with large scales of a cycloidal form, which overlap one another, and have wrinkled surfaces; and the tail is inequilobed. The teeth are of two sizes, and the larger ones are longitudinally striated at their bases. The true *Holoptychii* are Devonian in their distribution. In

the Carboniferous rocks, however, occur the superficially similar forms which constitute the genus *Rhizodus* (fig. 508), in which the teeth agree with those of *Holoptychius* in being of two sizes, but differ in being trenchant on both sides. The genus, again, differ from *Holoptychius*, and approaches *Megalichthys*, in having an obtusely-lobate pectoral fin, as is also the case in the allied *Rhizodopsis*. *Rhizodus* must have attained a large size, and must have been highly predaceous in its habits.

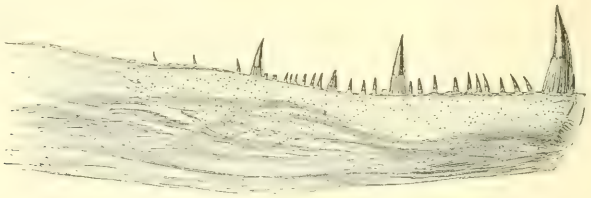

Fig. 508.—Jaw of *Rhizodus Hibberti*. Carboniferous.

We may also provisionally place near *Holoptychius* the genus *Onychodus*, from the Devonian of North America. In this genus are Ganoid fishes of large size having the cranium covered with bony plates, the surface of which is enamelled and tuberculated. The jaws carry numerous conical recurved teeth; and the scales (fig. 509) resemble those of *Holoptychius* in being cycloidal and overlapping, the under surface concentrically striated, and the exposed portion of the upper surface adorned with tubercular wrinkles.

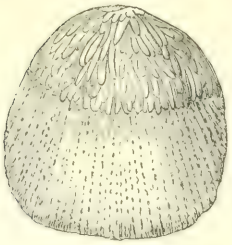

Fig. 509.—Upper surface of a scale of *Onychodus sigmoides*, of the natural size, from the Devonian of North America. (After Newberry.)

We may further place here the so-called "Dendrodont" Ganoids (*Dendrodus*, *Cricodus*, &c.), which are especially distinguished by the fact that the teeth have a singularly complicated and labyrinthine microscopic structure, somewhat resembling the pattern of the teeth in the Amphibian order of the *Labyrinthodontia*. The Dendrodonts are Devonian in their range.

The family *Phanopleurini* comprises only the single genus *Phaneropleuron* (fig. 510), which is probably exclusively Devonian. In this singular genus the scales are very thin, cycloidal, and overlapping one another. The dorsal fin is extremely long, and is confluent with the tail-fin, and the pectorals and ventrals are acutely lobate. The jaws are armed with a single series of short conical teeth, and the notochord was persistent.

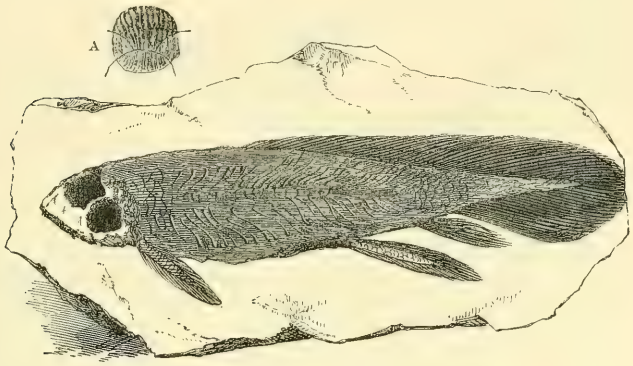

Fig. 510.—*Phaneropleuron Andersoni* and scale. Devonian.

Lastly, the family of the *Cœlacanthini* comprises forms which range from the Devonian to the Cretaceous period, and which are distinguished, in the typical genera, by having hollow fin-spines, by the possession of two dorsal fins, each supported by a single interspinous bone, by having cycloidal overlapping scales, and by the remarkable peculiarity that the swim-bladder was ossified. The type-genus *Cœlacanthus* seems to range from the Carboniferous to the Trias.

Sub-order E. Acanthodidæ.—Scales exceedingly small, shagreen-like; the front of each fin provided with a strong spine, simply implanted in the flesh; no distinctly ossified cranial bones; no operculum; tail heterocercal. In their fin-spines, and in some other points, the *Acanthodidæ* approximate closely to the *Elasmobranchii;* but they are generally regarded as an order of the *Ganoidei.* The *Acanthodidæ* are mainly Devonian, but some forms occur in the Carboniferous rocks, and two species from the Permian rocks have

been described. *Acanthodes* has a single dorsal fin, and is represented in both Devonian and Carboniferous deposits. *Cheiracanthus* (fig. 511, 1), of the Old Red Sandstone, is very similar to *Acanthodes*, but the single dorsal fin is placed in front of the anal. *Diplacanthus* (fig. 511, 3) has two dorsal fins, and is exclusively confined to the Devonian rocks.

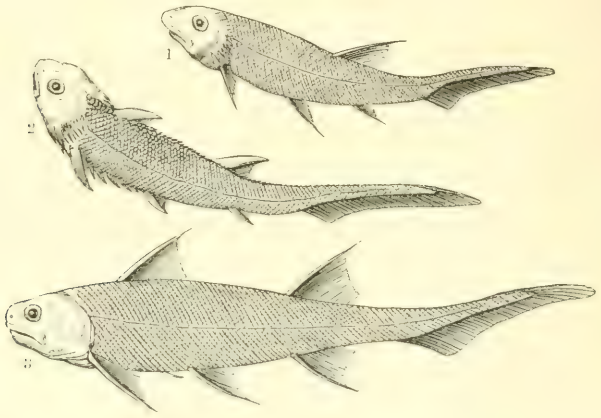

Fig. 511.—1, *Cheiracanthus Murchisoni*; 2, *Climatius scutiger*; 3, *Diplacanthus gracilis*. Devonian.

Sub-order F. Ostracostei.—The Ganoids of this sub-order, commonly known as "Placoderms," are characterised by having the head, and generally the anterior portion of the trunk as well, encased in a strong armour composed of numerous large ganoid plates, immovably united to one another. The posterior extremity of the body is more or less completely unprotected; and whilst the notochord is persistent, the peripheral elements of the vertebræ may be ossified. The fishes belonging to this section — if the piscine nature of the "Conodonts" be denied — are the most ancient of their class, commencing in the Upper Silurian rocks. They extend through the Devonian series, but are not known to have survived into the Carboniferous period. They have generally been placed amongst the Ganoids; but Professor Huxley has pointed out that they present, many of them, features by which they approximate

closely to the Siluroids amongst the Teleosteans. The more important genera included in this sub-order are *Cephalaspis*, *Pteraspis*, *Coccosteus*, and *Pterichthys*.

Cephalaspis (fig. 512) is the type of the family of the *Cephalaspidæ*, and is readily recognised by the fact that the cephalic shield has its posterior angles produced into long

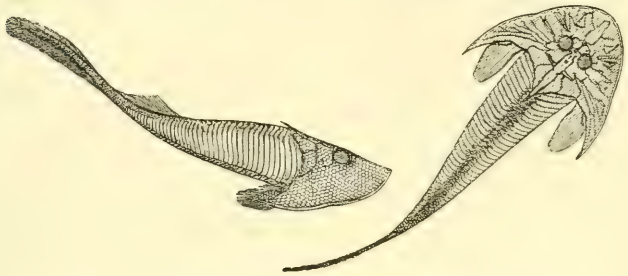

Fig. 512.—*Cephalaspis Lyellii*. (After Page.) Old Red Sandstone.

"cornua," giving it the shape of a "saddler's knife." Besides these lateral cornua, there is a "posterior cornu" or spine, formed by a prolongation backwards of the hinder margin of the shield in the middle line. The orbits are approximated, and are placed nearly in the centre of the cephalic shield. No jaws or teeth are known, and the mouth was probably soft, and adapted for suction. The head-shield exhibits vascular canals, and shows very distinct bone-cells when examined in thin sections under the microscope. The body is covered with ganoid scales, and there is a well-marked dorsal fin. Pectoral fins have also been described, and the tail is clothed with a heterocercal fin. In the nearly allied *Auchenaspis*, the structure is very similar to the above, but there is no spine or "posterior cornu," and there is instead a neck-plate formed by an extension backwards from the cephalic shield. The *Cephalaspidæ* are mainly found in the Old Red Sandstone, the commonest species being *C. Lyellii*. Other species are found in the "passage-beds" between the Silurian and Old Red, and the genus is not wholly unrepresented in the Upper Silurian deposits. The genus occurs not only in Europe, but also in the Devonian of North America.

In the genus *Pteraspis* (fig. 513) the head is defended, as in *Cephalaspis*, by a shield or buckler, which is composed of several pieces firmly anchylosed. The shield consists of a central disc, the lateral angles of which are produced into short cornua, whilst it is extended into a rostrum in front. The posterior spine is very small, and is attached to the disc as a separate piece. The orbits are situated laterally. The minute structure of the shield is very complex, consisting of three layers. The innermost layer is laminated, and is traversed by vascular canals. The middle layer is made up of polygonal cavities; and the outer layer is structureless or fibrous, and is finely striated or grooved. The body was covered with scales; but nothing is known of the nature of the fins. The genera *Cyathaspis* and *Scaphaspis* have been founded upon forms which have usually been placed under *Pteraspis*, and which differ in more or less essential points from the typical species of this genus. The genus *Pteraspis*,

Fig. 513. — Cephalic buckler of *Pteraspis* (*Cyathaspis*) *Banksii*. From the Upper Ludlow rocks of Ludlow. (After Murchison.)

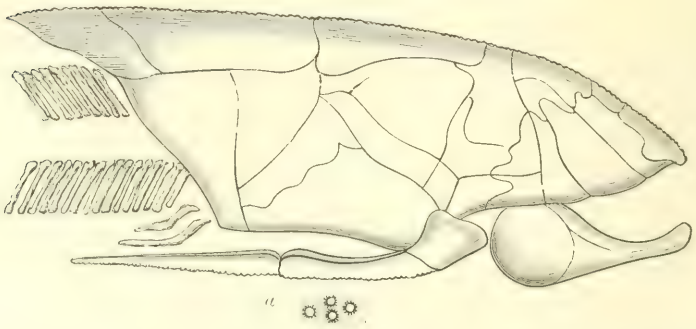

Fig. 514.—Cephalic shield of *Coccosteus decipiens*, viewed on one side, as restored by Pander —Old Red Sandstone. The surface-ornamentation is omitted, but a small portion is represented at *a*, on a larger scale.

so far as yet known, comprises the most ancient of the fishes, commencing as it does in the earlier portion of the Ludlow formation (Upper Silurian). Other species are known in the

Old Red Sandstone; but the genus appears to have entirely disappeared before the close of the Devonian period.

In the genus *Coccosteus* (fig. 514) the head was protected by a great shield, the plates of which are covered with small hemispherical tubercles. There is also a ventral or "sternal" shield, which, according to Huxley, seems to have had no direct connection with the cephalic buckler. The mouth was furnished with a distinct lower jaw or "mandible," composed of two rami, carrying small teeth. The notochord was persistent, but the neural and hæmal spines of the vertebræ, and the rays of the dorsal and anal fins, are well ossified. A heterocercal tail-fin was doubtless present as well. The genus *Coccosteus* is essentially Devonian; but a species has been discovered by M. Barrande in the Upper Silurian of Bohemia.

In the genus *Pterichthys* (fig. 515) are some very remarkable fishes, first discovered in the Old Red Sandstone by the late Hugh Miller, and nearly related in most respects to *Coc-*

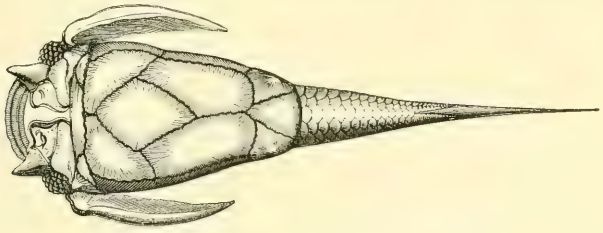

Fig. 515.—*Pterichthys cornutus.* Old Red Sandstone.

costeus. The whole of the head, together with the anterior part of the trunk, was defended by a buckler of large ganoid plates suturally united, those covering the trunk forming a backplate and a breastplate articulated together at the sides. The rest of the body was covered with small ganoid scales. A small dorsal fin, a pair of ventrals, a pair of pectorals, and a heterocercal tail-fin were present. The form of the pectoral fins is the peculiar characteristic of the genus. These were in the form of two long curved spines, somewhat like wings, covered by finely-tuberculated ganoid plates. From their form they cannot have been of much use in swimming; but they probably, as suggested by Owen, enabled the animal

to shuffle along the sandy bottom of the sea, if stranded at low water. All the species of *Pterichthys* are exclusively confined to the Old Red Sandstone. If, however, *Asterolepis* of Pander be identical with *Pterichthys*, then the genus was represented in the Upper Silurian.

We may also place in this neighbourhood the gigantic fishes of the Devonian of North America, for the reception of which Newberry has founded the genus *Dinichthys*. The head in this genus, sometimes measuring not less than three feet in length, was covered by a buckler of ganoid plates, resembling in form and arrangement the plates of the head-shield of *Coccosteus*, but having their surface adorned with granulations and furrows, in place of the stellate tubercles of the latter. The most remarkable feature in the genus, however, is the dentition, which closely resembles that of *Lepidosiren*, except in point of size, and which must have been associated with carnivorous and predaceous habits. Thus in the lower jaw (fig. 516) the extremity of each

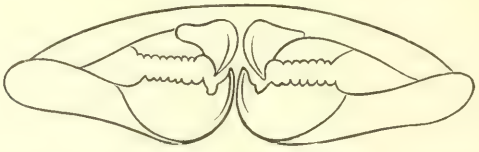

Fig. 516.—Diagram of the jaws and teeth of *Dinichthys Hertzeri*, viewed from the front, and greatly reduced in size. From the Devonian of North America. (After Newberry.)

ramus is bent upwards and pointed, so as to form a huge and sharp tooth on each side; the margins of the mandible behind these being enamelled for some distance, forming a sharp cutting edge, which may be entire or serrated. In the upper jaw, the tooth-like ends of the mandibular rami are confronted by two great præmaxillary teeth, of a triangular form, and the margins of the maxillæ on either side of these are either compressed and trenchant or actually denticulate.

Sub-order G. Chondrosteidæ (Sturionidæ).—In this sub-order the skeleton is almost altogether cartilaginous, and the notochord is persistent. The exoskeleton is usually in the form of large ganoid plates, which are united into a shield over the head, but are detached over the body. Sometimes

the exoskeleton is absent, and in no case is the mouth furnished with teeth. The tail is heterocercal.

This sub-order comprises the living Sturgeons (fig. 491), and is not known with certainty to have come into existence before the Eocene Tertiary, where it is represented by the *Acipenser toliapicus* of the London Clay. In the Lias, however, occur two species of the singular genus *Chondrosteus*, which have usually been referred here, and have been regarded as being most nearly allied to the Paddle-fishes (*Spatularia*) of North America. The skull, however, is more completely ossified than is the case with any living members of the *Sturionidæ;* and the true place of *Chondrosteus* must be regarded as uncertain.

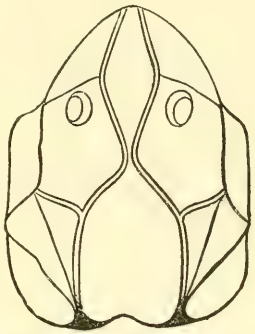

Fig. 517.—Diagram of the skull of *Macropetalichthys Sullivanti*, viewed from above, and greatly reduced in size. From the Devonian of North America. (After Newberry.)

We may also place here, at any rate provisionally, the Devonian genus *Macropetalichthys*, species of which are known to occur in both the Old and New Worlds. In this genus are included large fishes, in which the skull is protected by large polygonal ganoid plates (fig. 517), the surface of which is enamelled and tuberculated. The orbits are of large size, and both scales and teeth appear to have been entirely wanting.

CHAPTER XXXII.

ORDERS OF FISHES (Continued).

Order III. Elasmobranchii (= *Selachia*, Müller; *Placoidei*, Agassiz; *Holocephali* and *Plagiostomi*, Owen).—This order includes the Sharks, Rays, and Chimæræ, and corresponds with the greater and most typical portion of the *Chondropterygidæ* or Cartilaginous fishes of Cuvier. The order is distinguished by the following characters: *The skull and lower jaw are well developed, but there are no cranial bones, and the skull consists of a simple cartilaginous box, without any indication of sutures. The vertebral column is sometimes composed of distinct vertebræ, sometimes cartilaginous or sub-notochordal. The exoskeleton is in the form of placoid granules, tubercles, or spines. There are two pairs of fins, representing the limbs, and supported by cartilaginous fin-rays; and the ventral fins are placed far back near the anus. The pectoral arch has no clavicle. The heart consists of a single auricle and ventricle, and the bulbus arteriosus is rhythmically contractile, is provided with a special coat of striated muscular fibres, and is furnished with several transverse rows of valves. The gills are pouch-like.*

In most of the above characters it will be seen at once that the *Elasmobranchii* agree with the Ganoid fishes, especially as regards the structure of the heart. The following points of difference, however, require more special notice:—

1. The *exoskeleton* is what is called by Agassiz "placoid." It consists, namely, of no continuous covering of scales or ganoid plates, but of more or less numerous detached grains,

tubercles, or spines, composed of bony or dentinal matter, and scattered here and there in the integument. In the case of the Rays, these placoid ossifications often take a very singular shape, consisting of an osseous or cartilaginous disc, from the upper surface of which springs a sharp recurved spine, composed of dentine. The so-called "shagreen" of the Dog-fishes and Sharks is composed of very small and close-set tooth-like processes. At other times the placoid structures are developed into "dermal defences" or "ichthyodorulites." The minute structure of these exoskeletal structures is closely or entirely similar to that of the teeth. In some cases the exoskeleton is absent.

2. The *gills* are fixed and pouch-like, and differ very materially from those of the Bony and Ganoid fishes. In the case of the Sharks and Rays, the gill-pouches open upon the surface by a series of separate apertures, which are placed on the sides of the neck in the former, and on the under surface of the body in the latter. In neither is there any gill-cover or operculum, nor are there any branchiostegal rays. In one section of the order, however—viz., the *Holocephali*—though the internal structure of the gills is essentially the same as in the Sharks, there is only a single branchial aperture or gill-slit externally, and this is protected by a rudimentary operculum and branchiostegal rays.

The order *Elasmobranchii* is divided into the two suborders of the *Holocephali* and *Plagiostomi*. The former comprises the living *Chimæræ*, characterised by the mouth being terminal, and by there being only a single gill-slit. The latter comprises the living Port Jackson Shark, the true Sharks and Dog-fishes, and the Rays, characterised by having the mouth transverse and placed on the under surface of the head, whilst there are several apertures to the gills.

As regards their *general distribution in time*, the *Elasmobranchii* are nearly as ancient as the Ganoids. At the top of the Upper Ludlow rocks, or at the close of the Upper Silurian epoch, there have been discovered the remains of undoubted Plagiostomous fishes, most nearly allied to the existing Port Jackson Shark (*Cestracion Philippi*). These remains consist chiefly of defensive spines, which formed the

first rays in the dorsal fins, and upon these the genus *Onchus* (fig. 520) has been founded. Besides these there have been found portions of skin or "shagreen," with little placoid tubercles, like the skin of a living shark. These have been referred to the genera *Sphagodus* and *Thelodus*. They are the earliest known remains of Plagiostomous fishes, and with the exception of the few remains from the Lower Ludlow rocks, they are the earliest known remains of fishes in the stratified series. The discovery of these remains, at that time the earliest known traces of Vertebrate life, is due to the genius of Sir Roderick Murchison, the author of 'Siluria.'

Most of the fossil *Elasmobranchii* belong to the division *Cestraphori* of Owen, so called because they are provided with the large fin-spines which are known to geologists as "ichthyodorulites." The two families of this division—the Cestracionts and Hybodonts—are largely represented in past time, the former chiefly in the Palæozoic period, the latter chiefly in the Mesozoic rocks.

The true Sharks are represented in the earlier Mesozoic deposits (*e.g.*, by teeth of *Notidanus* in the Oolites); but they are chiefly Cretaceous and Tertiary. The teeth of *Odontaspis*, *Galeocerdo*, and *Carcharŏdon*, are good examples from the Eocene of the Isle of Sheppey. The true Rays are older than the true Sharks, occurring as early as the Carboniferous. Numerous remains of Rays, chiefly in the form of the pavement-like teeth, are known, both from the Secondary and Tertiary rocks. The last division of the *Elasmobranchii*—viz., that of the *Holocephali*—is poorly represented in past time by the *Rhynchodus* of the Devonian, and by the Mesozoic and Kainozoic *Ischiodus*, *Elasmodus*, *Ganodus*, and *Edaphodus*.

In the following a more detailed account is given of the characters of the various groups of the *Elasmobranchii* with the leading characters and more important fossil forms of each :—

Sub-order A. Holocephali.—This sub-order includes certain curious fishes, of which the only living forms are the *Chimæridæ*. The notochord is persistent, but the neural arches and transverse processes are cartilaginous. The jaws

are bony, and are covered by broad plates representing the teeth. The exoskeleton consists of placoid granules. The first ray of the anterior dorsal fin is in the form of a powerful defensive spine, like the "ichthyodorulites" of many fossil fishes. The ventral fins are abdominal, and the tail is heterocercal. There is only a single external gill-aperture, covered with a gill-cover and branchiostegal membrane; but only a small portion of the borders of the branchial laminæ is free. The mouth is placed at the extremity of the head.

The earliest known remains of Chimæroid fishes are those which Newberry has described from the Devonian of North America under the name of *Rhynchodus*, and (unless we place here the Devonian *Ptyctodus*, which may perhaps belong to a Dipnoan) they are the only traces of this group as yet found in the Palæozoic rocks. The remains upon which this genus is based consist of crescent-shaped or semicircular dental plates, the straight side of the tooth forming a triturating or cutting edge. In the Mesozoic and Kainozoic deposits, the remains of Chimæroids are not extremely rare, but they consist only of the jaws and teeth, along with fin-spines or "ichthyodorulites." The dental plates are united to the beak-shaped jaws (fig. 518); and the dorsal fin-spines are always movable and jointed—instead of being

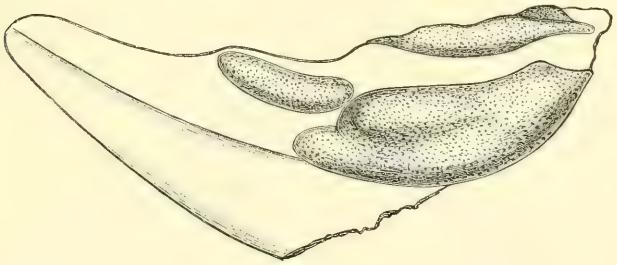

Fig. 518.—Lower jaw of *Edaphodus gigas*, viewed from above, showing the dental plates. Tertiary. (After Sir Philip Egerton.)

supported on a cartilage embedded in the muscular tissue of the back (as in the *Spinacidæ* and *Cestraciontidæ*). Of the fossil Chimæroids, the genera *Ischiodus* and *Ganodus* are exclusively Mesozoic; *Edaphodus* ranges from the Cretaceous

series to the Eocene Tertiary; and *Elasmodus* is only known from the Eocene.

Sub-order B. Plagiostomi.—This sub-order is of considerably greater importance, as it includes the well-known Sharks and Rays. The vertebral centra are usually more or less ossified, and even when quite cartilaginous, the centra are marked out by distinct rings. The skull is in the form of a cartilaginous capsule, without distinct cranial bones. The mouth is transverse, and is placed on the under surface of the head. The exoskeleton consists of placoid granules, tubercles, or spines. The branchial sacs open externally by as many distinct apertures as there are sacs, and there is no operculum.

By Professor Owen the *Plagiostomi* are divided into three sections, termed respectively the *Cestraphori*, the *Selachii*, and the *Batides*.

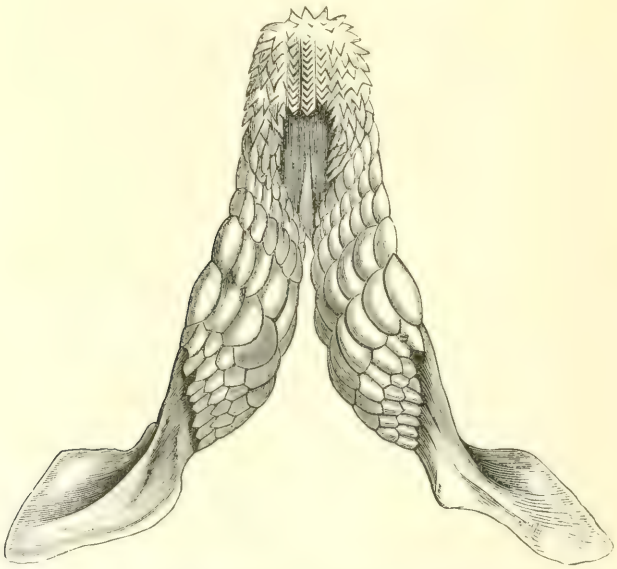

Fig. 519.—Upper jaw of Port Jackson Shark (*Cestracion*), showing the pavement of crushing teeth. One-half the natural size. (After Owen.)

a. Cestraphori.—In this division there is a strong spine in front of each dorsal fin, and the back teeth are obtuse. The

only living representatives of this group are the Port Jackson Sharks (*Cestracion*), characterised by their pavement of plate-like crushing teeth, adapted for comminuting small Molluscs and Crustaceans. They are exclusively inhabitants of the Australian and Chinese seas, and are remarkable for their close resemblance to a large group of extinct forms, of which the best known are the genera *Hybodus* and *Acrodus* from the Secondary rocks.

The *Cestraphori* are known in a fossil state mainly by their fin-spines, or "ichthyodorulites," and their teeth. It is obvious, however, that it must be often very difficult or altogether impossible to determine absolutely whether a spine or a piece of shagreen belongs to a Cestraciont or to a true Shark. Some of the forms, therefore, to be immediately mentioned, must be regarded as being only provisionally placed amongst the *Cestraciontidæ*.

With this proviso, the earliest known traces of Cestraciont fishes appear to be in the Upper Ludlow rocks, at the summit of the Silurian series. Here, within the limits of a single stratum, well known as the "bone-bed," occur remains which have been with more or less probability referred to Cestracionts. Some of these (fig. 520) are in the form of

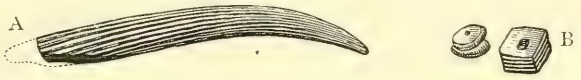

Fig. 520.—A, Spine of *Onchus tenuistriatus*; B, Shagreen-scales of *Thelodus*. Both from the bone-bed of the Upper Ludlow rocks.

compressed, slightly curved spines, the sides of which are grooved longitudinally. These have been referred to a provisional genus, under the name of *Onchus*, and there appears to be little doubt as to their truly belonging to fishes of some kind. It is, however, quite possible that they really belong to *Pteraspis*, in which case they must be removed from their present place.

Along with the spines of *Onchus* are found fragments of prickly skin or shagreen, which have been referred to the temporary genus *Sphagodus*, along with minute cushion-shaped bodies, which are doubtless placoid scales, and which

have been referred to another genus under the name of *Thelodus* (fig. 520, B). In the same bed are found jaw-like bodies, with tooth-like processes of different sizes, which have been named *Plectrodus*, and have been supposed to be the jaws of fishes. The true nature of these, however, is doubtful, and they certainly do not belong to Plagiostomous fishes. Possibly they are the prickly margins of the cephalic bucklers of Cephalaspidean fishes.

It should be mentioned, also, that M. Barrande enumerates *Ctenacanthus* amongst the fishes found in the Upper Silurian rocks of Bohemia, this genus being otherwise only known in the Devonian and Carboniferous formations.

In the Devonian rocks the remains of *Cestraphori* are not uncommon. The more important fossil spines of the deposits of this period have been referred to the genera *Onchus*, *Ctenacanthus*, *Homacanthus*, and *Cosmacanthus*. The fossil teeth belong chiefly to the genera *Ctenoptychius*, *Cladodus*, and *Psammodus*.

We may also mention here the singular spines upon which the genus *Machæracanthus* (fig. 521) has been founded,

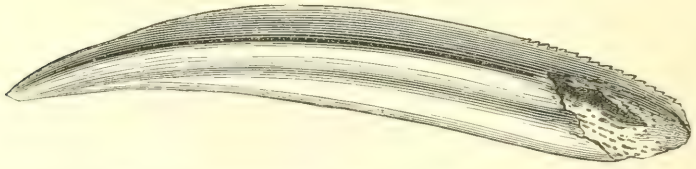

Fig. 521.—Fin-spine of *Machæracanthus major*, reduced in size. Devonian of North America. (After Newberry.)

though it is quite an open question whether these spines are referable to Cestracionts, Selachians, Chimæroids, or even Siluroids. They present, in fact, the singular peculiarity that they are unsymmetrical, in the sense that they are rights and lefts; and it seems almost impossible to account for this except upon the supposition that they were implanted in front of the *pectoral* and not of the *dorsal* fins. They are flattened, curved, and hollow, with an enamelled, smooth, or punctate surface; and they must have belonged to large and powerful fishes, as they are sometimes over

eighteen inches in length. Hitherto this genus has only been found in the Devonian of North America.

In the Carboniferous period the remains of *Cestraphori* are comparatively very abundant, though confined generally to particular localities. The spines of the Carboniferous

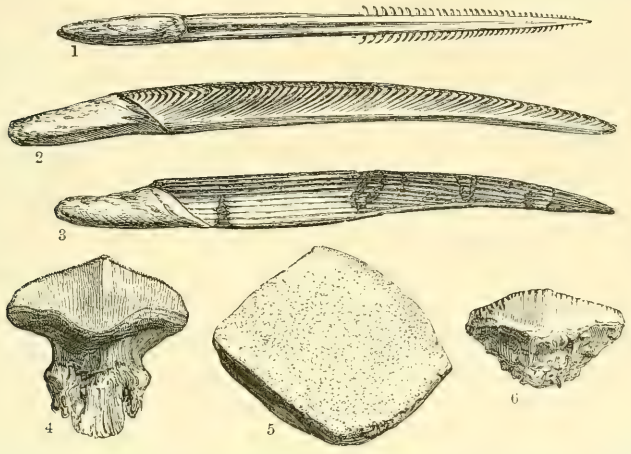

Fig. 522.—1, Fin-spine of *Pleuracanthus* (one of the Rays); 2, *Gyracanthus;* 3, *Ctenacanthus;* 4, Tooth of *Petalodus;* 5, *Psammodus;* 6, *Ctenoptychius*. All from the Carboniferous rocks.

strata have been referred to many genera, of which the most important are *Ctenacanthus* (fig. 522, 3), *Gyracanthus* (fig. 522, 2), *Homacanthus, Oracanthus, Onchus, Leptacanthus,* and *Edestes.* The fossil teeth of the Carboniferous rocks have also been referred to many genera, of which the more important are *Cochliodus* (fig. 523), *Deltodus, Psammodus, Orodus, Petalodus* (fig. 522, 4), *Ctenoptychius* (fig. 522, 6), *Cladodus, Centrodus, Glossodus, Diplodus, Helodus,* and *Petrodus.* Three principal types may be distinguished in these teeth. In one type (the "Cochliodonts"), as in *Cochliodus* (fig. 523) or *Psam-*

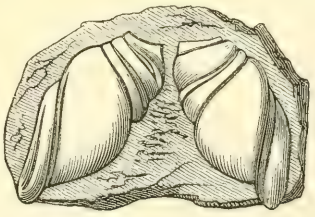

Fig. 523. — Dental plates of *Cochliodus contortus.* Mountain Limestone (Carboniferous).

modus, the teeth have the form of broad crushing plates, adapted for the comminution of Molluscs or Crustaceans. In fact, in these forms the teeth very closely resemble those of the living Port Jackson Shark (*Cestracion*). In the second type, as in *Cladodus*, *Orodus*, and *Glossodus*, the teeth are of what is called the "Hybodont" form, having a general conical shape, and consisting of a central principal cone, flanked by smaller secondary cones. A third group may be constituted for teeth of the type of *Petalodus* (fig. 522, 4), in which the teeth are concentrically wrinkled round their bases, transversely elongated, with a compressed petal-shaped expansion above, the summit of which forms a serrated cutting edge. The "Petalodonts" are characteristic of the Carboniferous rocks.

In the Permian series the remains of *Cestraphori* are scanty, but they are very numerous in all the great formations of the Secondary period. The four most important Mesozoic genera are *Hybodus*, *Acrodus*, *Strophodus* and *Ptychodus*.

In the genus *Hybodus* (fig. 524) the teeth are shark-like, but are not so trenchant as they are in the true Sharks.

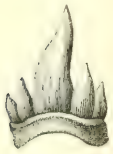

Fig. 524.—Tooth of *Hybodus*.

Fig. 525.—Fin-spine of *Hybodus*. Cretaceous.

They consist of a central "principal" cone, with smaller "secondary" cones on each side. The fin-spines (fig. 525) in this genus are longitudinally grooved, and carry a series of small teeth on their hinder or concave margin. Species of *Hybodus* abound in the Triassic and Jurassic formations, and occur, though less abundantly, in the Cretaceous rocks.

In the genus *Acrodus* (fig. 526) the teeth are more like those of the Port Jackson Shark. The front teeth are pointed and resemble those of the Hybodonts, but the back teeth are adapted for crushing shell-fish. Each of these crushing teeth

has an elongated form, with a rounded surface, which is covered with fine transverse striæ proceeding from a central longitudinal line. From their general form, colour, and striation, they are commonly called "fossil leeches" by the quarrymen. As in the case of *Hybodus*, the species of *Acrodus* are exclusively Mesozoic, ranging from the Trias to the Chalk.

Fig. 526.—Tooth of *Acrodus nobilis*. Lias.

The teeth of *Strophodus* are elongated, very similar to those of *Acrodus* in their general form, but truncated at both ends, and having their surface reticulated. Like the preceding, the species of *Strophodus* range from the Trias to the Chalk.

In the genus *Ptychodus*, lastly, the teeth are more or less quadrate in form, and the summit of the crown of the tooth is thrown into parallel transverse folds, ridges, or plications, surrounded by a granulated area. All the species of this genus are Cretaceous.

A few Tertiary forms of the *Cestraphori* have been described; but the affinities of most of these are doubtful. At the present day the family is represented only by the few species of the genus *Cestracion*.

b. Selachii. — This group comprises the Dog-fishes and Sharks, characterised by the elongated, not rhomboidal, form of the body, and by the lateral position of the gill-slits on the sides of the neck. The teeth are sharp and conical, and are arranged in several rows, of which the outermost alone is employed, the inner ones serving to replace the former when worn out.

This family attains its maximum at the present day, and its earliest authentic representatives appear in the Jurassic period. Some Palæozoic fossils, however, have been, with more or less probability, referred to Sharks, or placed in the neighbourhood of the living Monk-fishes (*Squatina*). With the exception of occasional vertebræ, all the known remains of *Selachians* consist of teeth.

In the Jurassic series are found teeth of *Notidanus* and

Sphenodus. In the Cretaceous rocks are numerous teeth, referred to the genera *Corax, Galeocerdo, Otodus, Lamna, Oxyrhina,* and *Odontaspis,* all of which continue to be represented in the Tertiary deposits. The teeth of *Carcharodon* (fig. 529) also occur in the Cretaceous series, but the genus is mainly Tertiary. The teeth in this genus are triangular, serrated on both sides, and sometimes of immense size (five or six inches in length). Teeth, apparently undistinguishable from *Carcharodon,* have been dredged from the bottom of the ocean at great depths, in considerable numbers, by the "Challenger Expedition." In *Otodus* (fig. 528) the teeth are not denticulated at their edges, and they have a secondary

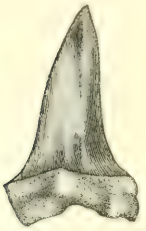

Fig. 527.—*Oxyrhina xiphodon.* Miocene.

Fig. 528.—*Otodus obliquus.* Eocene.

Fig. 529.—*Carcharodon productus.* Miocene.

tooth at each side of the base. The teeth of *Oxyrhina* (fig. 527), lastly, are large and compressed, differing from those of *Otodus* chiefly in wanting the lateral projections at the base. Upon the whole, the deposits which have yielded the greatest abundance of the teeth of these extinct Sharks, are the Upper Greensand (Cretaceous) and the London Clay (Eocene Tertiary).

c. Batides.—This group includes the Rays and Skates, and is distinguished by the fact that the branchial apertures are placed on the under surface of the body, forming two rows of openings a little behind the mouth. In the typical members of the group, the body is flattened out so as to form a kind of disc (fig. 530), the greater part of which is made up of the enormously developed pectoral fins. Upon the upper surface of the disc are the eyes and spiracles; upon the lower surface are the nostrils, mouth, and branchial apertures. The

flattened bodies of the Rays, however, must be carefully distinguished from those of the Flat-fishes (*Pleuronectidæ*). In the former, the flat surfaces of the body are truly the dorsal and ventral surfaces. In the latter, as before remarked, the body is flattened, not from above downwards, but from side to side, and the head is so twisted that both eyes are brought to one side of the body.

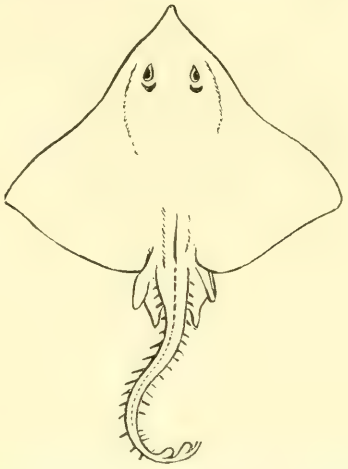

Fig. 530.—Batides. *Raia marginata*, one of the Skates. Reduced one-sixth. (After Gosse.)

The tail in the Rays is long and slender, usually armed with spines, and generally with two or three fins (the homologues of the dorsal fins). The mouth is paved with flat teeth of a more or less rhomboidal shape. The integument is often furnished with placoid structures of a peculiar shape consisting of oval or rounded osseous discs, from the centre of each of which springs a curved spine of dentine. The tail also is sometimes armed with a doubly-serrated defensive spine.

The Rays are known in the fossil condition by their flat crushing teeth mainly, but also by their fin-rays, bony discs, and defensive spines. The earliest trace of the Rays is found in the Carboniferous rocks, where occurs the doubly-serrated spine which is referred to the genus *Pleuracanthus* (fig. 522, 1). In this singular form, however, the spine seems to have been inserted at the back of the head, instead of in the tail, as in the living Sting-rays; and it is not certain that the genus is not rather truly Selachian in its affinities. Another ancient and remarkable form is *Janassa* (= *Climaxodus*), of the Carboniferous and Permian, which forms a connecting link between the Rays and the Cestracionts, though seemingly really referable to the former. In this genus, the mouth is furnished with ovate teeth (fig. 531), arranged in slightly

arched transverse rows in both upper and lower jaws. The upper surface of each tooth is hollowed out in front, with a sharp anterior edge, and is crossed behind by transverse ridges.

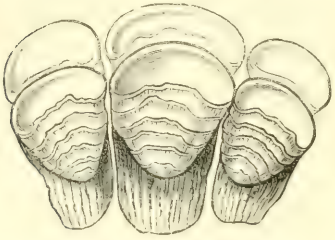

Fig. 531.—A few of the central teeth of *Janassa linguæformis*, about the natural size. Carboniferous. (After Hancock and Atthey.)

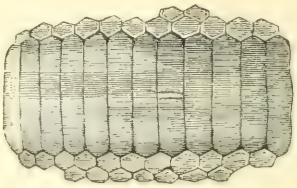

Fig. 532.—Teeth of a fossil Ray (*Myliobatis Edwardsii*). Eocene.

Janassa seems, upon the whole, to be most closely allied to *Myliobatis*, though its external teeth approximate in form to those of the "Petalodonts."

In the Jurassic rocks occur the remains of Rays, which have been referred to the genera *Squaloraia*, *Spathobatis*, *Arthropterus*, &c. In the Tertiary rocks the remains of Rays are tolerably abundant, and consist almost exclusively of the dental plates. These consist (fig. 532) of generally flat plates, usually somewhat rhomboidal in shape, often placed close together and sometimes united laterally by sutures, so as to "form a kind of mosaic pavement on both the upper and lower jaws" (Owen). Most of the fossil forms belong to the genus *Myliobatis*, which comprises the living Eagle-rays. All the fossil species of this family belong to the Tertiary period.

Order IV. Dipnoi (= *Protopteri*, Owen).—This order is a very small one, and includes, among recent forms, only the singular Mud-fishes (*Lepidosiren* and *Ceratodus*); but it is nevertheless of great importance as exhibiting a distinct transition between the Fishes and the *Amphibia*. So many, in fact, and so striking, are the points of resemblance between the two, that until recently the *Lepidosiren* (fig. 533) was always made to constitute the lowest class of the *Amphibia*. The highest authorities, however, now concur in placing it amongst the Fishes, of which it constitutes, with its allies, the highest order. The order *Dipnoi*

is defined by the following characters: *The body is fish-like in shape. There is a skull with distinct cranial bones and a lower jaw, but the notochord is persistent, and there are no vertebral centra, nor an occipital condyle. The exoskeleton consists of horny, overlapping scales, having the "cycloid"*

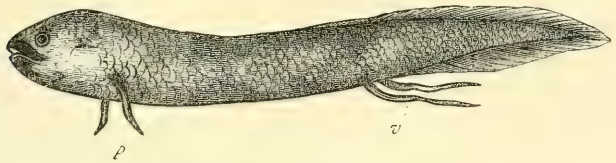

Fig. 533.—Dipnoi. *Lepidosiren annectens.*

Fig. 534.—*Ceratodus Forsteri.* The Australian Mud-fish.

character. The pectoral and ventral limbs are both present, but have (in Lepidosiren) the form of awl-shaped, filiform, many-jointed organs, of which the former only have a membranous fringe inferiorly; whereas in other cases (Ceratodus) they resemble these organs in the Crossopterygious Ganoids. The ventral limbs are attached close to the anus, and the pectoral arch has a clavicle; but the scapular arch is attached to the occiput. The hinder extremity of the body is fringed by a vertical median fin. The heart has two auricles and one ventricle, in Lepidosiren, but consists of an auricle, ventricle, and arterial bulb in Ceratodus. The respiratory organs are twofold, consisting on the one hand of free filamentous gills contained in a branchial chamber, which opens externally by a single vertical gill-slit; and on the other hand of true lungs in the form of a double cellular air-bladder, communicating with the œsophagus by means of an air-duct or trachea. The branchiæ are supported upon branchial arches, but these are not connected with the hyoid bone; and in some cases, at any rate, rudimentary external branchiæ exist as well. The nasal sacs open posteriorly into the throat.

Until lately the only known members of the order *Dipnoi* were the *Lepidosiren paradoxa* of South America and the

Lepidosiren (*Protopterus*) *annectens* of Africa. No fossil also could be referred with any certainty to this order. Recently, however, there has been discovered a most remarkable fish in the rivers of Queensland (Australia), which is certainly referable to this order, and which throws great light upon several fossil forms. The organisation of this fish is so extraordinary, and its affinities with some of the extinct Ganoids are so numerous and important, that it will be well to quote at some length the description of it given by Dr Albert Günther, one of the most eminent of living ichthyologists. The fish in question has been named the *Ceratodus Forsteri* (fig. 534), and it is known locally as the "Barramunda." It is said to attain a length of about six feet, but its average length is about three feet. The Barramunda "is eel-shaped, but considerably shorter and thicker than a common eel, and covered with very large scales. The head is flattened and broad, the eye lateral and rather small, the mouth in front of the broad snout and moderately wide. The gill-openings are a rather narrow slit on each side of the head. There are no external nostrils. The tail, which is of about the same length as the body without the head, is compressed, and tapers to a point, but it is surrounded by a very broad fringe, supported by innumerable fine and long fin-rays. There are two fore and two hind paddles, similar to each other in shape and size, and very different from the fins of ordinary fishes; their central portion being covered with a scaly skin, and the entire paddle surrounded by a rayed fringe. If we were to cut off the hind part of the tail of a fish, the piece would bear a strong resemblance to one of the paired paddles. The vent is situated in the median line of the abdomen between the paddles.

"In order to obtain a view of the inside of the mouth, it is necessary to slit it open, at least on one side. We then notice that there is a pair of nasal openings within and on each side of the cavity of the mouth. The palate is armed with a pair of large, long, dental plates, with a flattish undulated and punctated surface, and with five or six sharp prongs on the outer side, entirely similar to the fossil teeth described under the name of *Ceratodus*. Two similar dental

plates of the lower jaw correspond to the upper, their undulated surface fitting exactly to that of the opposite teeth. Besides these molars, the front part of the upper jaw (vomer) is armed with two obliquely-placed incisor-like dental lamellæ, which have no corresponding teeth in the lower jaw. As we know the kind of food taken by the Barramunda, the use of these teeth is apparent. The incisors will assist in taking up or even tearing off leaves, which are then partially crushed between the undulated surfaces of the molars.

"The skeleton consists of a cartilaginous basis, in the form of a long tapering chord for the body and tail, and in that of a capsule for the head. No segmentation into separate vertebræ is visible in any part of the notochord; but it supports a considerable number of apophyses, the abdominal of which bear well-developed ribs, all being solid cartilaginous rods, with a thin sheath of bone. In the same manner no part of the brain-capsule is ossified, but it is nearly entirely enclosed in thin bony lamellæ. This is also the structure of the appendages of the skull, as the mandible and the hyoid and scapulary arches. From a study of the skull, it becomes apparent at once why in fossil teeth of *Ceratodus* nothing or very little of the bone attached to them has been preserved. These teeth rest on cartilage as well as on bone, the latter being a very thin and porous layer which could not be preserved, unless the progress of stratification had been going on with as little disturbance as in the Solenhofen Schiefer; but the matrix in which fossil Ceratodont teeth are found shows that it was formed under very different conditions, and it is certainly not of a nature to permit the supposition that thin porous lamellæ of bone would have been preserved entire.

"The structure of the skeleton reminds us much of that of the Sturgeons, Chimæra, and especially of *Lepidosiren*; and of all the modifications by which it differs from these types, perhaps none is of greater interest than that observed in the paddles. The central part of the paddle, which we have found externally to be covered with scales, is supported by a jointed axis of cartilage extending from the root to the

extremity of the paddle; each joint bears a pair of three- or two- or one-jointed branches (fig. 489). This is the case in the hind as well as fore paddles, and we are justified in supposing that those extinct Ganoids of which impressions of paddles with scaly centres have been preserved, were provided with a similar internal skeleton."

Upon the whole, Dr Günther concludes: 1. That the Barramunda is not generically separable from the almost exclusively Triassic genus *Ceratodus*, which was founded simply upon detached teeth; 2. That the Barramunda is very closely allied to certain of the Crossopterygious Ganoids, such as the *Dipterus* of the Old Red Sandstone, the chief difference being, that the tail of the latter is heterocercal; 3. That the order *Dipnoi* should be considered merely as forming a sub-order of the *Ganoidei;* 4. That the *Ganoidei* may be united with the *Elasmobranchii* into a single group, which may be termed *Palæichthyes*, and which is characterised by having a "heart with a contractile bulbus arteriosus, intestine with a spiral valve, and optic nerves non-decussating;" 5. That the *Ganoidei* are the *Fresh-water Palæichthyes*, and the *Elasmobranchii* are the *Marine Palæichthyes.*

It would be out of place to enter here into any discussion of the systematic changes above mentioned, as proposed by this distinguished authority. Whether these views be ultimately adopted or not, it seems most convenient from a palæontological point of view, to retain the *Dipnoi* as a distinct *order* of the Fishes in the meanwhile. If this course be followed, we find that the order can readily, in the light of recent researches, be split into two distinct sections—the *Sirenoidei*, comprising *Lepidosiren* and *Ceratodus*, and the *Ctenodipterini*, comprising *Dipterus, Ctenodus*, and some other less important fossil forms.

In dealing with the first of these sections, we may leave *Lepidosiren* out of account, as it is not known to occur in a fossil state at all. The genus *Ceratodus*, however, has considerable geological importance, both intrinsically and from the light which it throws upon the real structure of the Ctenodipterines. The genus was originally founded by Agassiz to include certain singular dental plates (fig. 535)

from the Triassic rocks, the true relations of which were then, and for long after, quite obscure. We now know, however, from the happy discovery of the living *Ceratodus Forsteri*, that these teeth must have belonged to a Dipnoan

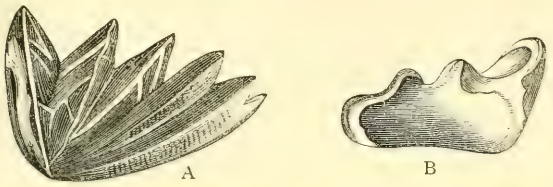

Fig. 535.—A, Dental plate of *Ceratodus serratus*—Keuper; B, Dental plate of *Ceratodus altus*—Keuper. (After Agassiz.)

fish, which must have resembled *Lepidosiren* in many respects, especially in its horny cycloidal scales, and its symmetrical tail and undivided dorsal fin, but which approached the Crossopterygious Ganoids in the fact that the fin-rays of the paired fins were arranged round a central scaly lobe. So far as is yet known, the genus *Ceratodus* does not occur in any deposit of Palæozoic age; but several species are known from the Trias, and a smaller number from the Jurassic rocks.

On the other hand, the section of the Ctenodipterines—distinguished from the preceding chiefly by the heterocercal form of the tail, the division of the dorsal fin into two, the possession of enamelled scales and cranial plates, and the existence of "gular plates" resembling those of the Crossopterygious Ganoids—has a much higher antiquity, not only dating from the Devonian, but being, so far as known, wholly Palæozoic in its range. The type-genus is *Dipterus* (fig. 536, A), of the Old Red Sandstone, in which the body is covered with cycloidal enamelled scales, the tail is extremely heterocercal, the skeleton is notochordal, and the pectoral fins are acutely lobate. The dental apparatus consists of two triangular, convex, ridged or tuberculated plates attached to the lower jaw (fig. 536, B), and of a pair of similar plates, which are attached to the roof of the mouth in the middle line. So far as is known, the genus *Dipterus* is exclusively confined to the Old Red Sandstone period. In the genus

Ctenodus, of the Devonian and Carboniferous, the scales are oblong and imbricated, of a thin and delicate texture, with a smooth central area bounded by concentric lines of growth.

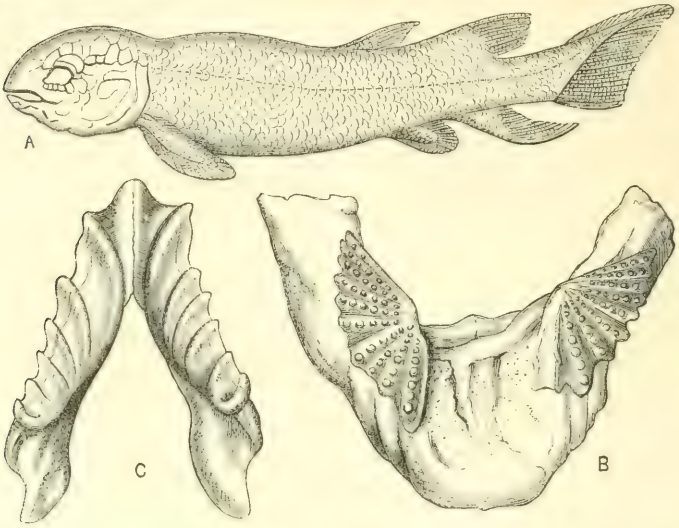

Fig. 536. — A, *Dipterus Valenciennesii*, reduced in size and restored—Old Red Sandstone (after Pander); B, Front portion of the lower jaw of *Dipterus platycephalus*—Old Red Sandstone — viewed from above and showing the dental plates (after Pander); C, Mandible of *Ctenodus imbricatus*, viewed from above, showing the dental plates, one-half of the natural size, from the Carboniferous (after Hancock and Atthey).

The skeleton is notochordal, and, as in *Dipterus*, enamelled cranial plates are present, while the dentition is of the type so characteristic of the latter genus. The lower jaw, namely, carries a pair of elongated dental plates (fig. 536, C), the upper surface of which is undulated by diverging ridges; and a corresponding pair of plates is attached to the roof of the palate. The genera *Holodus* and *Palædaphus* of the Devonian formation, have likewise been shown by Traquair to be referable to the Ctenodipterines; and we may also place here the Devonian genus *Conchodus*.

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CHAPTER XXXIII.

AMPHIBIA.

THE class *Amphibia* comprises the Frogs and Toads, the Salamandroids, the *Cæciliæ*, and the extinct *Labyrinthodonts*, and may be briefly defined as follows: As is the case with the Fishes, *branchiæ, or filaments adapted for breathing air dissolved in water, are always developed upon the visceral arches for a longer or shorter time. On the other hand, the Amphibians differ from the Fishes in the fact that true lungs are always present in the adult; the limbs are never converted into fins; and when median fins are present, as is sometimes the case, these are never furnished with fin-rays. The limbs, when present, exhibit in their skeleton the same parts as do the limbs of the higher Vertebrates. The skull always articulates with the vertebral column by means of two occipital condyles. The heart consists of two auricles and a single ventricle. The nasal sacs communicate posteriorly with the pharynx; and the rectum, ureters, and ducts of the reproductive organs open into a common chamber or "cloaca."*

The great and distinguishing character of the *Amphibia* is the fact that they undergo a *metamorphosis* after their exclusion from the egg. They commence life as water-breathing larvæ, provided with gills or branchiæ; but in their adult state they invariably possess lungs; the branchiæ in the higher forms disappearing when the lungs are developed, but being in other cases permanently retained throughout life.

In the earliest embryonic condition the branchiæ are *external*, placed on the side of the neck, and not situated in an

internal chamber as in Fishes. In some cases the external branchiæ only are present, and they are, in any case, the gills which are retained in those forms in which the branchiæ are permanent (*Perennibranchiata*). In the tailed Amphibians (*Urodela*) and in the Frogs and Toads (*Anoura*) two sets of gills are developed—an external set, which is very soon lost, and an internal set, which is retained for a longer or shorter period. As maturity is approached, true lungs adapted for breathing air are developed. The development, however, of the lungs varies with the completeness with which aerial respiration has to be accomplished; being highest in those forms which lose their gills when grown up (*Caducibranchiata*), and lowest in those in which the branchiæ are retained throughout life (*Perennibranchiata*).

The class *Amphibia* is divided into the four orders of the *Ophiomorpha*, *Urodela*, *Anoura*, and *Labyrinthodontia*. The first of these includes only the serpentiform animals known as *Cæciliæ*, and not having any certain fossil representatives, may be altogether passed over here. The order *Urodela* comprises the so-called "tailed" Amphibians of the present day, such as the Newts and Salamanders. The earliest traces of this order in past time, with some doubtful exceptions, occur in the Tertiary deposits. The order *Anoura* includes the so-called "tail-less" Amphibians, such as the Frogs and Toads, and is not known to have existed in periods anterior to the Tertiary. Lastly, the order *Labyrinthodontia* is entirely extinct, and is known to have existed mainly during the Carboniferous, Permian, and Triassic periods.

Order I. Urodela (= *Ichthyomorpha*, Owen; *Saurobatrachia*).—This order is commonly spoken of collectively as that of the "Tailed" Amphibians, from the fact that the larval tail is always retained in the adult. The *Urodela* are characterised by having the skin naked and almost invariably destitute of any exoskeleton. The body (fig. 537) is elongated posteriorly to form a compressed or cylindrical tail, which is permanently retained throughout life. The dorsal vertebræ are biconcave (*amphicœlous*), or concave behind and convex in front (*opisthocœlous*), and they have short ribs

attached to the transverse processes. The bones of the fore-arm (*radius* and *ulna*) on the one hand, and those of the shank (*tibia* and *fibula*) on the other, are not anchylosed to form single bones.

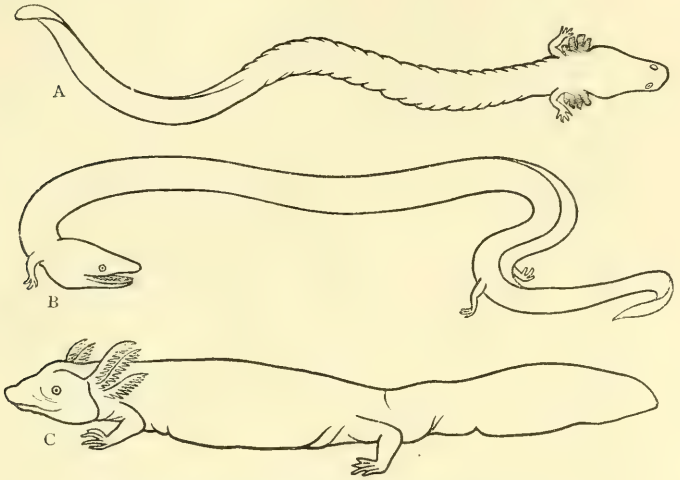


Fig. 537.—Tailed Amphibians. A, *Siren lacertina*; B, *Amphiuma*, showing the four minute limbs; C, *Menobranchus maculatus*. (After Mivart.)

The best known of the existing *Urodela* are the Newts (*Triton*), the Salamanders (*Salamandra*), the Mud-eels (*Siren*), the Axolotl (*Siredon*), and the Giant-salamanders (*Menopoma*). Some of these are "perennibranchiate," retaining the branchiæ throughout life; others lose the branchiæ, becoming thus "caducibranchiate," but retain the branchial apertures behind the head; others, lastly, lose both the branchiæ and the branchial apertures. Most of the *Urodela* have the four limbs well developed, but some possess only the anterior limbs.

The geological history of the *Urodela* is short, and of comparatively little importance. The most ancient forms which have been referred to this order are the *Palæosiren* of Geinitz and the *Protriton* of Gaudry; but the true position of these is not altogether certain. The former is from the Lower Permian, and is believed by its discoverer to be a Urodelan, and to be most nearly allied to *Siren lacertina*;

but it may in reality belong to the *Labyrinthodontia*. *Protriton*, on the other hand, is from strata of Carboniferous

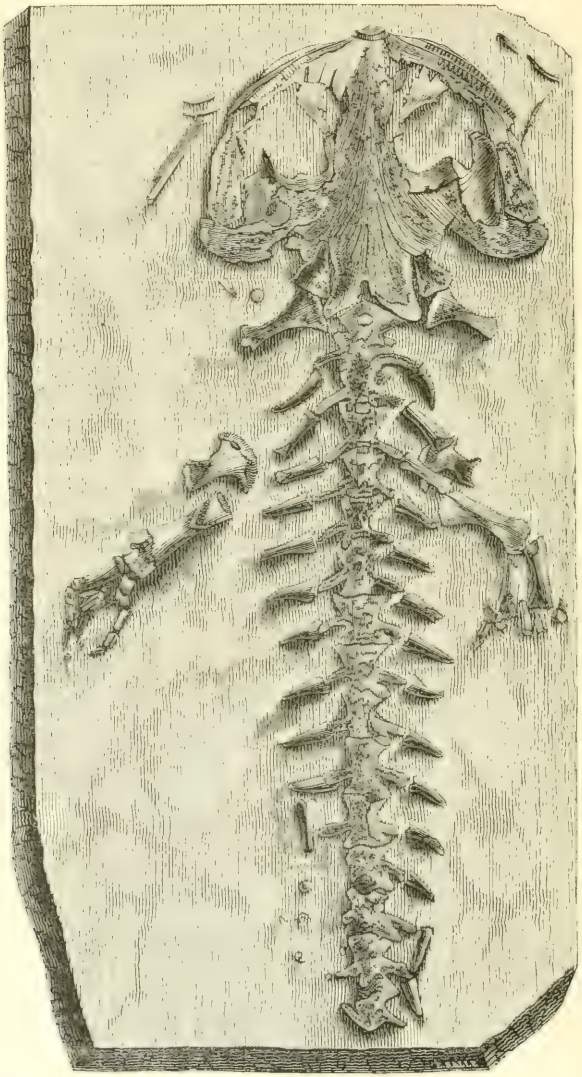


Fig. 538.—*Andrias Scheuchzeri*. Miocene Tertiary.

(possibly Permian) age, and would appear to have stronger

claims to be regarded as a true Urodelan. Its skin seems to have been naked; the head is larger than that of *Salamandra*, and the tail relatively much shorter; the orbits being very large, the ribs short, and the limbs short and tetradactylous. M. Gaudry suggests, further, that the *Apateon terrestris* and *Pelion* (*Raniceps*) *Lyelli* of the Carboniferous may turn out to be Urodelans allied to *Protriton*.

With the above exceptions, if they really be such, the order *Urodela* has not hitherto been shown to have existed in times anterior to the Tertiary. In strata of this age have been discovered the remains of Salamandroids in all fundamental respects resembling the now existing types. The most remarkable of these is the *Andrias Scheuchzeri* (fig. 538) of the Miocene beds of Oeningen. This singular fossil was described by its original discoverer as human, under the name of *Homo diluvii testis;* but it is really the skeleton of a Salamandroid of large size. It is very closely allied to the Giant-salamander (*Menopoma*, or *Sieboldia*, *maxima*) of Java.

Order II. Anoura (= *Batrachia*, Huxley; *Theriomorpha*, Owen; *Chelonobatrachia*, &c.)—This order includes the Frogs and Toads, and is perhaps best designated by the name of *Anoura*, or "Tail-less" Amphibians. The name *Batrachia*, employed by Huxley, is inexpedient, partly because it is used by Owen to designate the entire class *Amphibia*, and partly because, in common language, it is usual to understand by a "Batrachian" any of the higher Amphibians; such, for instance, as a Labyrinthodont.

The *Anoura*, or Tail-less Amphibians, are characterised by the following points: The adult is destitute of both gills and tail, both of which structures exist in the larva, whilst the two pairs of limbs are always present. The skin is soft, and there are rarely any traces of an exoskeleton. The dorsal vertebræ are "procœlous" or concave in front, and are furnished with long transverse processes, which take the place of ribs, which are only present in a rudimentary form. The radius and ulna in the fore-limb, and the tibia and fibula in the hind-limb, are anchylosed to form single bones (fig. 539). The mouth is sometimes edentulous, but the upper jaw has

usually small teeth, and the lower jaw sometimes. The hind-limbs usually have the digits webbed for swimming, and are generally much larger and longer than the fore-limbs.

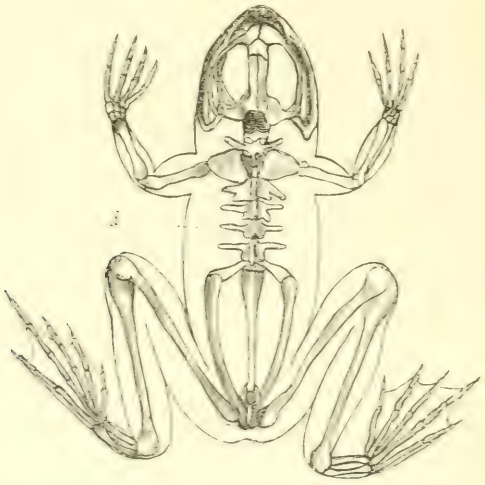


Fig. 539.—Skeleton of the common Frog (*Rana temporaria*). *d*, Dorsal vertebræ, with long transverse processes.

The geological history of the *Anoura*, as in the case of the *Urodela*, is of small importance. The two chief groups of the living *Anoura*—namely, the Frogs and the Toads—are both represented in past time; but they do not appear to have come into existence till after the commencement of the Tertiary period. Most of the fossil forms have been detected in deposits of Miocene age.

Order IV. Labyrinthodontia.—The members of this, the last order of the Amphibia, are entirely extinct. They were Batrachians, probably most nearly allied to the *Urodela*, but mostly of large size, and some of gigantic dimensions, the skull of one species (*Labyrinthodon Jaegeri*) being upwards of three feet in length and two feet in breadth. The Labyrinthodonts were first known to science simply by their footprints, which were found in certain sandstones of the age of the Trias. These footprints consisted of a series of alternate pairs of hand-shaped impressions, the hinder print of each

pair being much larger than the one in front (fig. 541). So like were these impressions to the shape of the human hand, that the unknown animal which produced them was at once christened *Cheirotherium*, or "Hand-beast." Further discoveries, however, soon showed that the footprints of *Cheirotherium* had been produced by different species of Batrachians, to which the name of Labyrinthodonts was applied in consequence of the complex microscopic structure of the teeth.

The order *Labyrinthodontia* is thus defined by Professor Huxley: "The body is salamandriform, with relatively weak limbs and a long tail. The dorsal vertebræ, when completely ossified, are biconcave, with double transverse processes. The ribs have distinct capitula and tubercula.

"In the thoracic region, three superficially sculptured exoskeletal plates, one median and two lateral, occupy the place of the interclavicle and clavicles. Between these and the pelvis is a peculiar armour, formed of rows of oval dermal plates (fig. 540), which lie on each side of the middle line of the abdomen, and are directed obliquely forwards and inwards, to meet in that line.

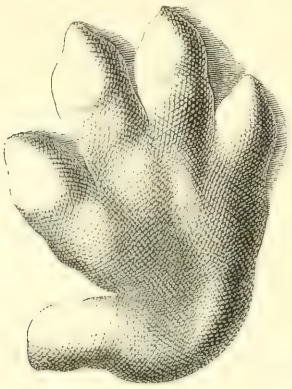
Fig. 540.—One of the integumentary scutes of *Anthracosaurus Russelli*, one-half of the natural size. Coal-measures. (After Atthey.)

"The skull has distinctly ossified epiotic bones, in the same position and of the same form as those of fishes. The cranial bones are sculptured, and many exhibit peculiar smooth symmetrical grooves —the so-called 'mucous canals.'

"The parietes of the teeth are deeply plaited and folded, so as to give rise to a complicated 'labyrinthine' pattern in the transverse section of the tooth."

There appear usually to have been both pairs of limbs developed, but some forms which have been referred here (such as *Ophiderpeton*) possessed a serpentiform body, and seem to have been apodal. Little is known, necessarily, of their development, but the singular genus *Archegosaurus* possessed permanent branchial arches, and was, therefore, apparently perennibranchiate (if not truly a larval form), whilst its noto-

chord was persistent, and simply had rings of osseous matter deposited in it.



The points in which the Labyrinthodonts differ from the modern *Urodela* are chiefly to be found in the fact that the head is defended by an external covering or helmet of hard and polished osseous plates, in the possession of ventral integumentary scutes, in the existence of exoskeletal plates occupying the place of the interclavicle and clavicles, in the amphicœlous form of the dorsal vertebræ, and in the complicated structure of the teeth. These

Fig. 541.—Footprints of a Labyrinthodont (*Cheirotherium*), from the Trias. The upper figure shows a single footprint enlarged; the lower figure shows a slab, with several prints, and traversed by reticulated desiccation-cracks.

last-mentioned organs are not only often very numerous, but are of large size. The subjoined illustration (fig. 542) shows the beautiful and complex structure of the teeth, from which the name of the order is derived.

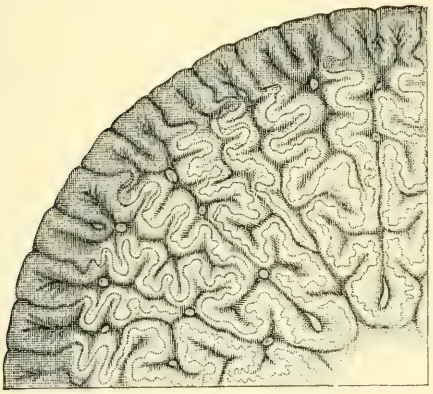


Fig. 542.—Section of the tooth of *Labyrinthodon* (*Mastodonsaurus*) *Jægeri*, showing the microscopic structure. Greatly enlarged. Trias.

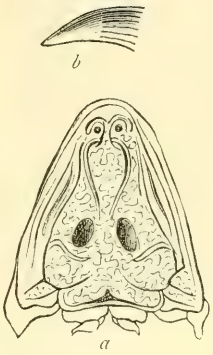


Fig. 543.—*a*, Skull of *Labyrinthodon Jægeri*, much reduced in size; *b*, Tooth of the same. Trias, Würtemberg.

As regards their general distribution in time, the Labyrinthodonts range from the Carboniferous rocks to the Lias; but some of the forms commonly included in this order may perhaps belong elsewhere. One type of the Labyrinthodonts is constituted by the singular genus *Archegosaurus*, and the less known *Apateon*—both from the Carboniferous rocks. *Archegosaurus* is remarkable in having the notochord persistent, and in the possession of permanent branchial arches. It has been made by Professor Owen the type of a separate group, the *Ganocephala;* but it is probably an immature and larval form. The occipital condyles, also, do not seem to have been ossified in the *Archegosauria*.

Of the Carboniferous Labyrinthodonts the most important genera are *Anthracosaurus*, *Pteroplax*, *Loxomma*, *Keraterpeton*, *Pholidogaster*, *Ophiderpeton*, *Ichthyerpeton*, *Urocondylus*, *Lepterpeton*, *Baphetes*, *Raniceps*, *Dendrerpeton*, *Hylerpeton*, and *Hylonomus;* though the affinities of some of these are more or less doubtful. Most of the Carboniferous Labyrinthodonts

were of comparatively small size; but some, such as *Baphetes* and *Anthracosaurus* (fig. 544), must have attained gigantic dimensions. All the above-mentioned genera seem to have possessed well-ossified vertebræ, with, mostly,

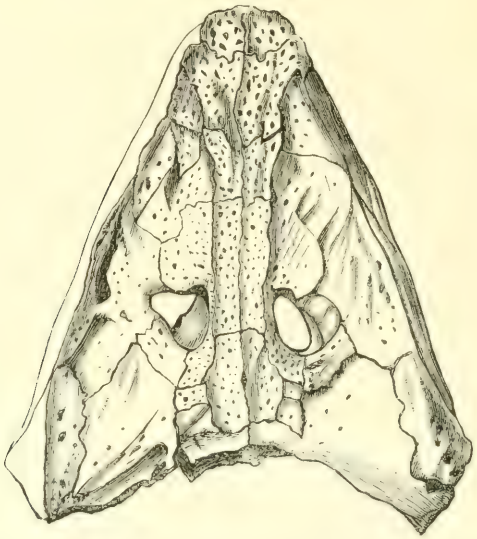


Fig. 544.—Upper surface of the skull of *Anthracosaurus Russelli*, one-sixth of the natural size. Coal-measures. (After Atthey.)

well-developed limbs, the form of the body being mostly salamandriform, but sometimes fish-like, or serpentiform. *Ophiderpeton*, however, is believed to have been devoid of limbs.

In the Permian rocks, a few remains of Labyrinthodonts have been discovered, the genus *Zygosaurus* being peculiar to this period.

In the Triassic rocks the remains of Labyrinthodonts are abundant, the most important genus being *Labyrinthodon* or *Mastodonsaurus* (fig. 543). This genus is known mainly by footprints and by crania; and the size attained by some species must have been colossal. No remains of this order have hitherto been discovered in rocks younger than the Trias, with the exception of the Liassic *Rhinosaurus*, and the doubtfully Jurassic *Brachyops*. The absence of examples of

this large and varied order in the Cretaceous and Tertiary deposits, coupled with the fact that Amphibians of an altogether modern type occur in the early part of the last of these periods, seems to render it certain that the evolution

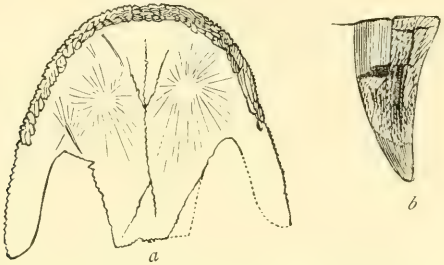


Fig. 545.—*Baphetes planiceps*, from the Carboniferous rocks of Nova Scotia (after Dawson). *a*, Anterior part of the skull, viewed from beneath, and much reduced; *b*, One of the largest teeth—natural size.

of the now existing orders of *Amphibia* must have taken place through some other channel than through the Labyrinthodonts.

In the later portion of the Palæozoic period, however, and in the earlier part of the Mesozoic, we have evidence of the existence of an immense number of forms belonging to the Labyrinthodonts. Many of these forms are at present very imperfectly known; often they have been described from only very fragmentary remains; and it would be altogether out of the question to give here anything like even a general account of their peculiarities. It may be of advantage, however, to subjoin here the classificatory table of the order which has been drawn up by Prof. Miall, who has devoted special attention to this group of fossils.

Tabular View of the Classification of the Labyrinthodontia.

A. *Centra of dorsal vertebræ discoidal*—(Genera 1 to 23).

I. Euglypta.—Cranial bones strongly sculptured; lyra conspicuous; mandible with a well-developed post-articular process. Teeth conical, their internal structure complex; dentine much folded. Palato-vomerine tusks in series with small teeth; a short inner series of mandibular teeth. Sculptured thoracic plates, with a reflected process upon the external border.

* *Palatine foramina large, approximated.*

† *Mandible with an internal articular process.*

‡ *Orbits central or posterior.*

1. Mastodonsaurus.
2. Capitosaurus.
3. Pachygonia (?).
4. Trematosaurus.
5. Gonioglyptus.

‡‡ *Orbits anterior.*

6. Metopias.
7. Labyrinthodon.

†† *Mandible without internal articular buttress.*

8. Diadetognathus.

** *Palatine foramina small, distant.*

9. Dasyceps.
10. Anthracosaurus.

II. Brachyopina.—Skull parabolic ; orbits oval, central or anterior. Post-articular process of mandible wanting (?).

11. Brachyops.
12. Micropholis.
13. Rhinosaurus.
14. Bothriceps.

III. Chauliodonta.—Skull vaulted, triangular, with large postero-lateral expansions. Lyra consisting of two nearly straight longitudinal grooves, continued backwards as ridges. Orbits moderate or large, posterior. Temporal depressions passing backwards from the orbits. No post-articular process to the mandible. Teeth unequal, clustered.

* *Teeth with large anterior and posterior cutting-edges.*

15. Loxomma.

** *Teeth conical.*

16. Zygosaurus.
17. Melosaurus.

IV. Arthroödonta.—Maxillary teeth wanting. Vomerine teeth aggregated. Orbit imperfect.

18. Batrachiderpeton.
19. Pteroplax.

[V. An uncharacterised group for the reception of some or all of the following genera.]

20. Pholidogaster.
21. Ichthyerpeton.
22. Pholiderpeton.

VI. Archegosauria. — Vertebral column notochordal. Occipital condyles unossified.

23. Archegosaurus.

B. *Centra of dorsal vertebræ elongated, contracted in the middle*—(Genera 24 to 31).

VII. Heleothrepta.—Skull triangular, with a produced, tapering snout. Orbits central. Mandibular symphysis very long, about half the length of the skull.

24. Lepterpeton.

VIII. Nectridea.—Epiotic cornua much produced. Superior and inferior processes of caudal vertebræ dilated at the extremities and pectinate.

25. Urocordylus.
26. Keraterpeton.

IX. Aïstopoda.—Limbs wanting.

27. Ophiderpeton.
28. Dolichosoma.

X. Microsauria.—Thoracic plates unknown. Ossification of limb-bones incomplete. Dentine nearly or altogether non-plicate; pulp-cavity large.

29. Dendrerpeton.
30. Hylonomus.
31. Hylerpeton.

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CHAPTER XXXIV.

REPTILIA.

The true Reptiles and the Birds, unlike as they are in external appearance, are nevertheless related to one another by various points of affinity; so that they may well be included in a single division, which has been termed *Sauropsida* by Huxley. The *Sauropsida* are defined by the possession of the following characters: *At no period of existence are branchiæ, or water-breathing respiratory organs, developed upon the visceral arches; the red corpuscles of the blood are nucleated; the skull articulates with the vertebral column by means of a single articulating surface or condyle; and each half or "ramus" of the lower jaw is composed of several pieces, and articulates with the skull, not directly, but by the intervention of a peculiar bone, called the "quadrate bone," or "os quadratum"* (fig. 546).

These being the common characters of Reptiles and Birds, by which they are collectively distinguished from other Vertebrates, it remains to inquire what are the characters by which they are distinguished from one another. The following, then, are the characters which separate the Reptiles from the Birds: *The blood in Reptiles is cold—that is to say, slightly warmer than the external medium—owing mainly to the fact that the pulmonary and systemic circulations are always directly connected together, either within the heart or in its immediate neighbourhood, so that the body is supplied with a mixture of venous and arterial blood, in place of pure arterial blood alone. The terminations of the bronchi at*

the surface of the lung are closed, and do not communicate with air-sacs, placed in different parts of the body. When the epidermis develops horny structures, these are in the form of horny plates or scales, and never in the form of feathers. The forelimbs are formed for various purposes, including in some cases even flight, but they are never constructed upon the type of the "wings" of Birds. Lastly, with one or two doubtful exceptions, whilst the ankle-joint is placed between the distal and proximal portions of the tarsus, the tarsal and metatarsal bones of the hind-limb are never anchylosed into a single bone.

These are the leading characters by which Reptiles are distinguished from Birds; but we must not forget the other distinctive peculiarities in which Reptiles agree with Birds, and differ from other Vertebrates—namely, the absence of branchiæ at all times of life, the possession of only one occipital condyle, and the articulation of the complex lower jaw with the skull by means of a quadrate bone.

It is now necessary to consider these characteristics of the *Reptilia* a little more minutely. The class includes the Tortoises and Turtles, the Snakes, the Lizards, the Crocodiles, and a number of extinct forms; and with the exception of the Tortoises and Turtles, they are mostly of an elongated cylindrical shape, provided posteriorly with a long tail. The limbs may be altogether absent, as in the Snakes, or quite rudimentary, as in some of the Lizards; but as a general rule both pairs of limbs are present, sometimes in the form of ambulatory legs, sometimes as swimming-paddles, and in some extinct forms modified to subserve an aerial life. The endoskeleton is always well ossified, and is never cartilaginous or semi-cartilaginous, as in many Fishes and some Amphibians. The skull articulates with the atlas by a single condyle. The lower jaw is complex, each half or ramus being composed of from four to six pieces, united to one another by sutures (fig. 546). In the Tortoises, however, these are anchylosed into a single piece, and the two rami are also anchylosed. In most Reptiles, however, the two rami of the lower jaw are only loosely united—in the Snakes by ligaments and muscles only, in the Lizards by fibro-cartilage, and in the *Crocodilia* by a regular suture. In all, the lower

jaw articulates with the skull by a quadrate bone (fig. 546, *a*); and as this often projects backwards, the opening of the mouth is often very extensive, and may even extend beyond the base of the skull. Teeth are usually present, but are not sunk in separate sockets or alveoli, except in the Croco-

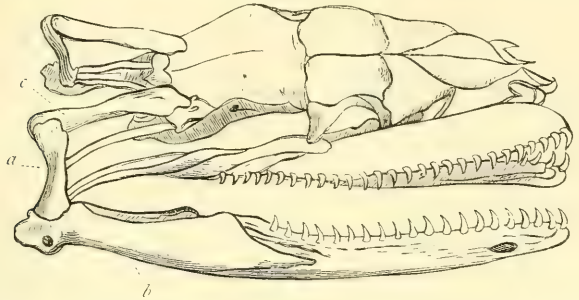

Fig. 546.—Skull of a Serpent (*Python*) *b*, Articular portion of the lower jaw; *a*, Quadrate bone; *c*, Squamosal portion of the temporal bone.

diles and in some extinct forms. In the Tortoises and Turtles alone of living types there are no teeth, and the jaws are simply sheathed in horn, constituting a kind of beak like that of a bird.

Ribs are always present and always well developed, but they differ much in form. It is not correct, however, to regard the presence of ribs as separating the true Reptiles from the *Amphibia*, as is sometimes stated. Some of the most Lizard-like of the Amphibians, such as the Siren, possess short but well-developed ribs, and rudiments of ribs are traceable in other orders; whilst in the *Cæciliæ* they are large and well developed.

As regards the exoskeleton, all Reptiles have horny epidermic scales, and they are divided into two great sections—called respectively *Squamata* and *Loricata*—according as the integumentary skeleton consists simply of these scales, or there are osseous plates developed in the derma as well. In the Tortoises, the epidermic plates unite with the bony exoskeleton and with the true endoskeleton to form the case or box in which the body of these animals is enclosed.

The class *Reptilia* is divided into the following ten orders, of which the first four are represented by living forms, whilst the remaining six are extinct:—

1. *Chelonia* (Tortoises and Turtles).
2. *Ophidia* (Snakes).
3. *Lacertilia* (Lizards).
4. *Crocodilia* (Crocodiles and Alligators). } Recent.
5. *Ichthyopterygia.*
6. *Sauropterygia.*
7. *Anomodontia.*
8. *Pterosauria.*
9. *Deinosauria.*
10. *Theriodontia.* } Extinct.

As regards their general *distribution in time*, the *Reptilia* attained their maximum of development in the Mesozoic period, which has hence often been called the "Age of Reptiles." If the Elgin Sandstones, containing the remains of *Telerpeton* and *Stagonolepis*, be of Triassic age—as seems almost certain—then no Reptile has as yet been discovered in the Devonian rocks. In the Carboniferous rocks, the place of the true Reptiles seems to have been taken by the Amphibian group of the Labyrinthodonts. It is possible, however, that the little *Hylonomus*, of which three species were discovered in the Coal-strata of Nova Scotia by Dr Dawson, may be Lacertian in its affinities. It is also possible that the vertebræ from strata of the same age described by Professor Marsh under the name of *Eosaurus Acadiensis*, may belong to a marine reptile allied to *Ichthyosaurus*. In the Permian rocks the first undoubted Reptilian remains occur, the *Protorosaurus* of this period being a Lacertilian, and other forms being known as well from deposits of the same age.

Throughout the whole Mesozoic series, Reptilian remains are abundant and belong to numerous and strange types. Chelonians and true Crocodiles, with Lizards allied to existing forms, make their first appearance in deposits belonging to this period. The extinct orders of the *Ichthyopterygia*, *Sauropterygia*, *Anomodontia*, *Pterosauria*, *Theriodontia*, and *Deinosauria*, not only first appear in Mesozoic deposits, but are exclu-

sively confined to rocks of this age. In the Tertiary period, lastly, the remains of Reptiles are comparatively rare, and the number of types is much reduced. The living order of the *Ophidia*, however, makes its first appearance in the Tertiary deposits. In the following view of the characters and distribution in time of the orders of the Reptiles, it will be advisable to consider the recent orders first, though this is not in accordance with their natural arrangement.

Order I. Chelonia.—The first order of living Reptiles is that of the *Chelonia*, comprising the Tortoises and Turtles, and distinguished by the following characters: *There is an osseous exoskeleton which is combined with the endoskeleton to form a kind of bony case or box in which the body of the animal is enclosed, and which is covered by a leathery skin, or, more usually, by horny epidermic plates. The dorsal vertebræ are immovably connected together, and are devoid of transverse processes. The ribs are greatly expanded (fig. 547, r), and are united to one another by sutures, so that the walls of the thoracic cavity are immovable. All the bones of the skull except the lower jaw and the hyoid bone are immovably united together. There are no teeth, and the jaws are incased in horn so as to form a kind of beak. The heart is three-chambered, the ventricular septum being imperfect.*

Of these characters of the *Chelonia*, the most important and distinctive are the nature of the jaws and the structure of the exoskeleton and skeleton. As regards the first of these points, the lower jaw in the adult appears to consist of a single piece, its complex character being masked by anchylosis. The separate pieces which really compose each ramus of the jaw are immovably anchylosed together, and the two rami are also united in front by a true bony union. There are also no teeth, and the edges of the jaws are simply sheathed in horn, constituting a sharp beak. As regards the second of these points, the bony case in which the body of a Chelonian is enclosed consists essentially of two pieces, a superior or dorsal piece, generally convex, called the "carapace," and an inferior or ventral piece, generally flat or concave, called the "plastron." The carapace and plastron are firmly united along their edges, but

are so excavated in front and behind as to leave apertures for the head, tail, and fore and hind limbs. The limbs and tail can almost always be withdrawn at will under the

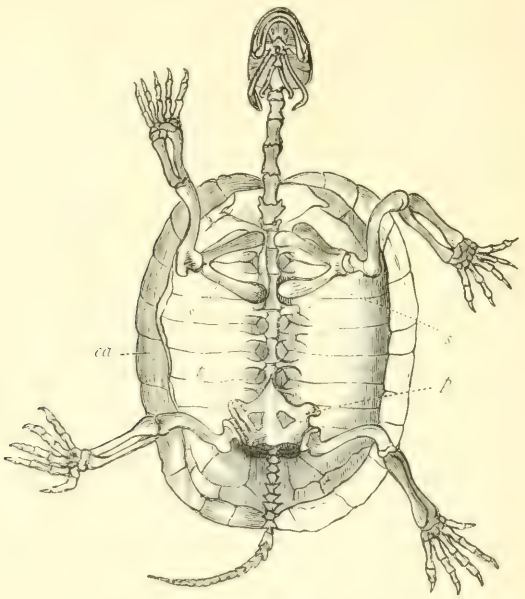

Fig. 547.—Skeleton of Tortoise (*Emys Europæa*), the plastron being removed. *ca*, Carapace; *r*, Ribs, greatly expanded, and united by their edges; *s*, Scapular arch, placed within the carapace, and carrying the fore-limbs; *p*, Pelvic arch, also placed within the carapace, and carrying the hind-limbs.

shelter of the thoracico-abdominal case formed in this way by the carapace and plastron, and the head is also generally retractile.

The carapace or dorsal shield (fig. 548) is composed of the following elements:—

1. The spinous processes of the dorsal vertebræ, which are much flattened out laterally and form a series of broad plates, which are eight in number, and are termed the "neural plates" (*n*). 2. The ribs (*r*, *r*) are united with broad and flattened plates of bone (*c'*, *c'*), which are connected with one another by lateral sutures, and are known as the "costal plates." In some cases, however, the costal plates, instead of being united by the whole of their lateral

margins, leave marginal apertures towards their extremities, and these openings are simply covered by a leathery skin or by horny plates. 3. The margin of the carapace is completed by a series of bony plates, which are called the "marginal plates" (fig. 548, *m*, *m*). These are variously regarded as being dermal bones belonging to the exo-

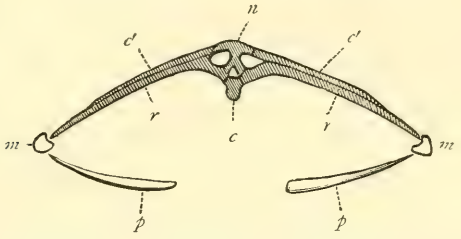

Fig. 548.—Transverse section of the skeleton of *Chelone midas* in the dorsal region. *c*, Body of one of the dorsal vertebræ; *n*, Expanded spinous process or "neural plate" of the same; *r*, *r*, Ribs; *c'*, *c'*, "Costal plates;" *m*, *m*, Marginal plates; *p*, *p*, Lateral elements of the plastron. (After Huxley.)

skeleton, or as being endoskeletal, and as representing the ossified cartilages of the ribs (in this last case the marginal plates would correspond with what are known as the "sternal ribs" of Birds). Of these marginal plates the one in the middle line of the carapace in front is known as the "nuchal" plate, and is larger than the rest, while the corresponding plate behind is termed the "pygal" plate, (see fig. 550, *nu* and *py*).

The "plastron" or ventral shield (fig. 549) is composed of nine bony pieces, of which eight are in pairs, and the ninth is odd. Of the paired pieces, the anterior are the *episternals*, the middle pair the *hyosternals*, and the hinder pair the *hyposternals*, while the unpaired piece is termed the *xiphisternal* (fig. 549, *xs*). The precise nature of the bones of the plastron is still a matter of some doubt. Some regard them as wholly corresponding with the sternum or breast-bone; others regard them as wholly integumentary; while others, again, hold—what is doubtless the correct opinion—that the plastron is formed partly of bones belonging to the endoskeleton proper and representing the sternum, in part at any rate, and partly of integumentary ossifications.

Both the carapace and plastron are covered by a series of horny plates (rarely wanting), which are developed in the

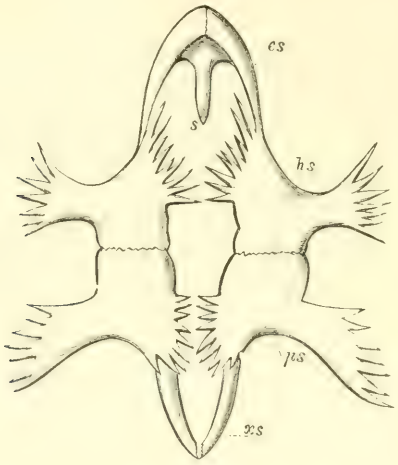

Fig. 549.—Bones of the plastron of the Loggerhead Turtle (*Chelone caouanna*). *s*, Entosternal; *es*, Episternal; *hs*, Hyosternal; *ps*, Hyposternal; *xs*, Xiphisternal. (After Owen.)

epidermis, and which are perfectly distinct from the bones which they cover. As encasing the upper surface of the carapace, these plates have a general arrangement conforming with that of the bony plates beneath, though there is no numerical correspondence between the two. Thus the carapace, as we have seen, consists of (1) a median series of "neural" plates developed from the vertebræ; (2), a lateral series of "costal" plates on each side, corresponding with and largely formed by the ribs; and (3), a peripheral series of "marginal" plates (see fig. 550). Similarly, the epidermic plates (fig. 550) are arranged in (1) a median, "vertebral" or "neural" series; (2), a lateral series on each side of "costal" scutes; and (3), a series of "marginal" scutes. The "vertebral" scutes, however, are only *five* in number; and each series of "costal" scutes consists only of *four* pieces, so that the number of epidermic plates is much smaller than that of the bony plates beneath. The "marginal" scutes, on the other hand, correspond in number with the "marginal

plates" beneath them. They are, therefore, twenty-four or twenty-six in number, the anterior scute in the middle line being distinguished by the epithet of "nuchal," while the corresponding scute behind is termed "pygal."

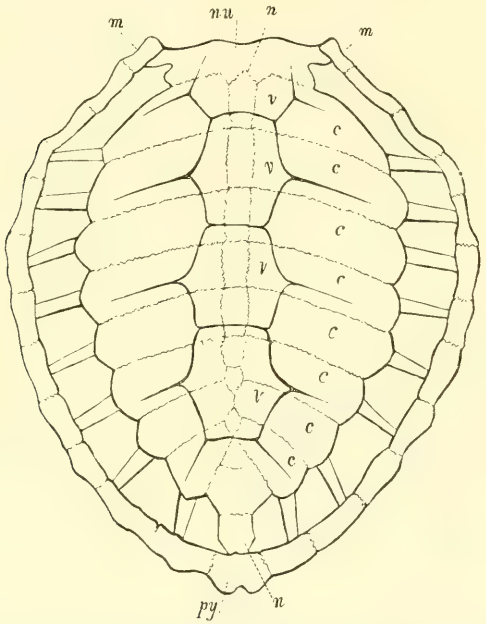

Fig. 550.—Carapace of the Loggerhead Turtle (*Chelone caouanna*), viewed from above (after Owen). In this form, the ribs are separate and free towards their extremities, and the osseous portions of the carapace are indicated by the light lines, while the epidermic plates are marked out by dark lines. *n*, *n*, The first and last of the median series of "neural plates;" *c*, *c*, The expanded ribs or "costal plates;" *m*, *m*, The first "marginal plate" on each side; *nu*, Nuchal plate; *py*, Pygal plate; *v*, *v*, Median series of epidermal plates, or "vertebral scutes."

The only remaining points connected with the skeleton which may be just noticed are that the scapular and pelvic arches, supporting respectively the fore and hind limbs, are placed within the carapace; and that, as in the *Crocodilia*, clavicles are wanting. The three anterior pieces of the plastron may, however, represent an interclavicle and clavicles.

From the aquatic habits of many of the members of this order they are by no means uncommon in the fossil condition. The Turtles frequent the sea, and thus come natu-

rally to be fossils in marine deposits; and the preservation of all the Chelonians alike is rendered easy by the indestructible nature of the case in which their bodies are enclosed.

The Chelonians may be divided into sections according as the limbs are natatory, are adapted for an amphibious life, or are fitted for terrestrial progression. In the first of these sections are the true Turtles (*Cheloniidæ*), which frequent the sea, and are distinguished by their depressed and flattened carapace, and by their oar-like limbs. In the second section are the River and Marsh Tortoises, comprising the Soft Tortoises (*Trionycidæ*) and the Terrapins (*Emydidæ*). In the third section are the true Land-tortoises (*Testudinidæ*), distinguished by their strongly convex carapace, and limbs adapted for walking upon the land. All these three sections are represented in past time, the Turtles, *Trionycidæ*, and *Emydidæ* appearing for the first time, so far as is certainly known, in the Jurassic series, whilst the *Testudinidæ* do not appear till the commencement of the Tertiary epoch. The earliest apparent traces of Chelonians occur in the Permian rocks, in the lower portion, that is, of the New Red Sandstone of the older geologists. These traces, however, are not satisfactory, since they consist solely of the footprints of the animal upon the ripple-marked surfaces of the sandstone. Of this nature is the *Chelichnus Duncani*, described by Sir William Jardine in his classical work on the 'Ichnology' of Annandale in Dumfriesshire. It is not, however, till we

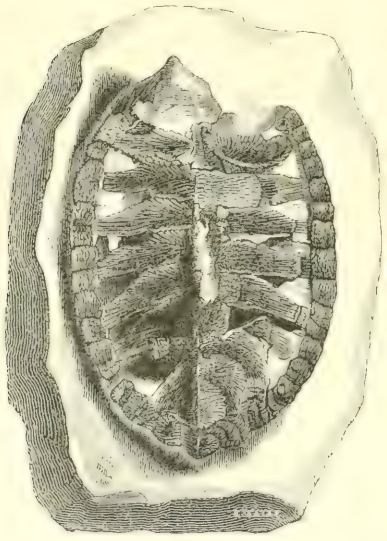

Fig. 551.—*Chelone Benstedi*. Lower Chalk.

reach the Jurassic period that we meet with unequivocal remains of Chelonian Reptiles. Here the true Turtles (*Cheloniidæ*) make their first undoubted appearance with the *Chelone planiceps* of the Portland Stone (Upper Jurassic). In the Cretaceous series we have evidence of the existence of numerous forms of Chelonians, one of which is here figured. It is also in deposits of this age that the earliest traces of Chelonians that have yet been found in North America occur. Some of these (*e. g.*, *Atlantochelys*) are forms allied to the true Turtles, while there are other genera related to the *Emydidæ*.

In the Tertiary rocks the remains of Turtles are abundant, and especially so in the London Clay (Eocene). Species of *Emydidæ* have been cited from the Jurassic series, some of which appear to be free from doubt. A species of *Emys* occurs in the Wealden, and numerous forms of this family have been detected in formations of Tertiary age, especially in the Eocene and Miocene. The *Trionycidæ*, except for a femur described by Owen from the Lias, are not known to have existed prior to the commencement of the Tertiary period. Numerous species of *Trionyx*, however, occur in the Eocene, and others have been described from the Miocene and Pliocene. The *Testudinidæ* or Land-tortoises appear to have commenced their existence in the Miocene Tertiary. The most remarkable form of this group is the huge *Colossochelys Atlas* of the Upper Miocene (? Pliocene) deposits of the Siwâlik Hills in India, described by Dr Falconer and Sir Proby Cautley. Far exceeding any living Tortoise in its dimensions, this enormous animal is estimated as having had a length of about twenty feet, measured from the tip of the snout to the extremity of the tail, and to have stood upwards of seven feet high. All the details of its organisation, however, prove that it must have been "strictly a land animal, with herbivorous habits, and probably of the most inoffensive nature." The accomplished palæontologists just quoted, show, further, that some of the traditions of the Hindoos would render it not improbable that this colossal Tortoise had survived into the earlier portion of the human period. The largest living Tortoises are found in the Gala-

pagos Islands; but Dr Günther has shown that several gigantic species of *Testudo* formerly inhabited the islands of Mauritius and Rodriguez.

Order II. Ophidia.—The second order of Reptiles is that of the *Ophidia*, comprising the Snakes and Serpents, and distinguished by the following characters:—

The body is always more or less elongated, cylindrical, and worm-like, and whilst possessing a covering of horny scales, is always unprovided with a bony exoskeleton. The dorsal vertebræ are concave in front (procœlous), with rudimentary transverse processes. There is never any sternum, nor pectoral arch, nor fore-limbs, nor sacrum, and, as a rule, there are no traces of hind-limbs. Rudimentary hind-limbs, however, are occasionally present (*e. g.*, in *Python* and *Tortrix*). *There are always numerous ribs. The two halves or rami of the lower jaw are composed of several pieces, and the rami are united anteriorly by ligaments and muscles only, and not by cartilage or suture. The lower jaw, further, articulates with the skull by means of a quadrate bone, which is always more or less movable, and is in turn united with the squamous portion of the temporal bone ("mastoid bone"), which is also movable, and is not firmly united with the skull. The superior maxillæ are united with the præmaxillæ by ligaments and muscles only, and the palatine arches are movable and armed with pointed recurved teeth. Hooked conical teeth are always present, but they are never lodged in distinct sockets or alveoli.* Functionally, they are capable of performing nothing more than merely holding the prey fast, and the Snakes are provided with no genuine masticatory apparatus. The heart has three chambers, two auricles, and a ventricle, the latter imperfectly divided into two cavities by an incomplete septum. The lungs and other paired organs are mostly not bilaterally symmetrical, one of each pair being either rudimentary or absent.

The vertebral column in the Snakes is always composed of very numerous vertebræ, which are divisible only into a caudal and precaudal series. The atlas is the only precaudal vertebra which does not bear ribs; while in the caudal region the place of ribs is taken by elongated trans-

verse processes. The anterior surface of the neural arches of the vertebræ is produced into a process, or "zygosphene," each of which fits into a corresponding cavity, or "zygantrum," in the hinder surface of the neural arch of the vertebra just in front.

The three most important groups of the existing Ophidians are the Colubrine Snakes, the Constricting Snakes, and the Viperine Snakes. In the first of these the upper jaws carry solid teeth, with or without canaliculated fangs as well. In the second group are the Boas and Pythons, distinguished by their great size, enormous muscular power, and numerous strong recurved teeth. In the third group are Snakes, in which the upper jaws carry only a pair of perforated poison-fangs.

Most of the existing Snakes are terrestrial in their habits, and are therefore not likely to be preserved in stratified deposits. Many of these, however, take to the water occasionally, and some habitually frequent rivers or the sea itself. All the above-mentioned groups of Ophidians are represented in past time, but they are neither abundant nor of importance as fossils. No remains of Ophidians are known to occur in any Palæozoic or Mesozoic deposit. The earliest known traces of any serpent are in the Lower Kainozoic rocks, one of the oldest being the *Palæophis toliapicus* of the London Clay of Sheppey. The nearly-allied *Palæophis typhæus* of the Eocene beds of Bracklesham appears to have been a Boa-constrictor-like snake of about twenty feet in length. In the Eocene deposits of North America occur various remains of Snakes. Some of these seem to have frequented the sea (such as *Titanophis* or *Dinophis*), and to have been large serpents allied to the *Palæophis* of the European area. Others, again (*Boavus*, *Limnophis*, *Lithophis*), are found in lacustrine strata, and appear to have been related to the Boa-constrictors, but to have been of moderate size. In some of the later Tertiary deposits have been found the poison-fangs of a venomous snake. Upon the whole, however, the Snakes must be looked upon as a comparatively modern group, and not as one of any great geological antiquity.

Order III. Lacertilia.—The third order of Reptiles is that of the *Lacertilia*, comprising all those animals which are commonly known as Lizards, together with some serpentiform animals, such as the Blind-worms. The *Lacertilia* are distinguished by the following characters:—

As a general rule, there are *two pairs of well-developed limbs, but there may be only one pair, or all the limbs may be absent. A scapular arch is always present, whatever the condition of the limbs may be. An exoskeleton, in the form of horny scales like those of the Snakes, is almost always present. The vertebræ of the dorsal region are procœlous or concave in front, rarely amphicœlous or concave at both ends.* There is a single transverse process at each side, and the heads of the ribs are simple and undivided. There is either no sacrum, or the sacral vertebræ rarely exceed two in number. *The teeth are not lodged in distinct sockets (some extinct forms constituting an exception to this statement). The eyes are generally furnished with movable eyelids. The heart consists of two auricles and a ventricle, the latter partially divided by an incomplete partiton. There is a urinary bladder, and the aperture of the cloaca is transverse.*

As a general rule, the animals included under this order have four well-developed legs (fig. 552), and would therefore be popularly called "Lizards." In some (*Chirotes*) there are

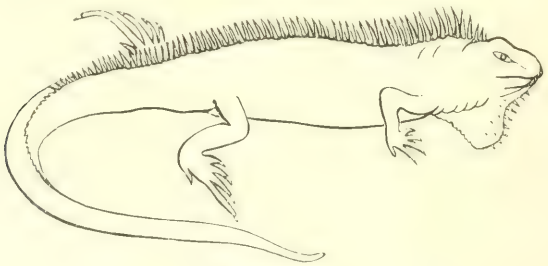

Fig. 552.—Iguana.

no hind-feet; in some (*Bipes*) the fore-limbs are wanting; and others (*Anguis, Pseudopus,* and *Amphisbæna*) are entirely destitute of limbs, thus coming closely to resemble the true Snakes or Ophidians in external appearance. These

serpentiform Lizards, however, can be distinguished from the true Snakes, amongst other characters, more especially by the structure of the jaws. In the Snakes, as before said, the two rami of the lower jaw are loosely united in front by ligaments and muscles, and are attached behind to a movable quadrate bone, which is in turn connected with a movable squamosal, this giving an enormous width of gape to these animals. In the Lizards however, even in those most like the Snakes, the halves of the lower jaw are firmly united to one another in front, and though the quadrate bone is usually more or less movable, the jaws can in no case be separated to anything like the extent that characterises the *Ophidia*.

The Lizards are distinguished from the Crocodiles, amongst other characters, by the fact that the integumentary covering is in the form of horny scales, very rarely accompanied by bony "scutes," whilst the teeth are rarely sunk into distinct sockets. All the living Lacertilians and almost all the extinct forms possess teeth, which may be confined to the jaws proper, or may be also developed on the palatine and pterygoid bones. The teeth are always simple, sometimes sharp and conical (*Monitor*), sometimes blade-like, with serrated edges (*Iguana*), sometimes with broad crushing crowns (*Cyclodus*). Usually the teeth become anchylosed with the jaw, becoming either attached by their sides to the parapet of the jaw ("pleurodont" dentition), or fixed by their bases to the top of the parapet ("acrodont" dentition). In the extinct *Protorosaurus* the teeth are sunk in distinct sockets ("thecodont" dentition).

The whole order of the *Lacertilia* is often united with the next group of the *Crocodilia*, under the name of *Sauria*. The term "Saurian," however, is an exceedingly convenient one to designate all the reptiles which approach the typical Lizards in external configuration, whatever their exact nature may be; and from this point of view it is often very useful as applied to many fossil forms, the structure of which is only imperfectly known. It is therefore perhaps best to employ this term merely in a loose general sense.

It is hardly possible, with our present knowledge, to speak

very positively as to the exact range of the *Lacertilia* in time. This uncertainty arises from two causes—firstly, that there is some doubt as to the exact age of some deposits which have yielded Lacertilian remains; and secondly, that the affinities of some extinct Reptiles are a matter of considerable question. Upon the whole, the oldest known Lacertilian would appear to be the *Protorosaurus* (fig. 553) of the

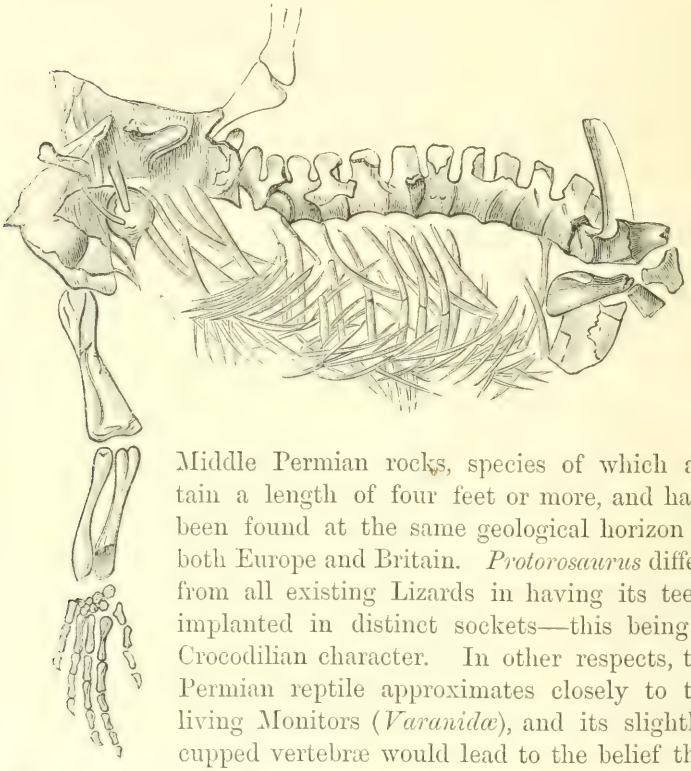

Fig. 553.—*Protorosaurus Speneri*—Middle Permian, Thuringia—reduced in size. (After Von Meyer.)

Middle Permian rocks, species of which attain a length of four feet or more, and have been found at the same geological horizon in both Europe and Britain. *Protorosaurus* differs from all existing Lizards in having its teeth implanted in distinct sockets—this being a Crocodilian character. In other respects, the Permian reptile approximates closely to the living Monitors (*Varanidæ*), and its slightly-cupped vertebræ would lead to the belief that it was aquatic in its habits.

In rocks known, or supposed, to be of Triassic age, numerous Lacertilian reptiles have been discovered, of which the most important are *Telerpeton*, *Hyperodapedon*, and *Rhynchosaurus*. *Telerpeton* occurs in strata near Elgin, in Scotland, which have been variously referred to the Upper

Devonian and to the Trias, but which almost certainly belong to the latter. Professor Huxley concludes that *Telerpeton* "presents not a single character approximating it towards the type of the Permian *Protorosauria*, nor to the Triassic *Rhynchosaurus*, and other (probably Triassic) African and Asiatic allies of that genus, nor to the Mesozoic *Dinosauria*; still less can it be considered a 'generalised' form, or as, in any sense, a less perfectly organised creature than the Gecko, whose swift and noiseless run over walls and ceilings surprises the traveller in warmer climates than our own." In its dentition, *Telerpeton* seems to have been "acrodont," and it differs from most existing Lizards merely in having amphicœlous, and not procœlous, vertebræ.

Hyperodapedon was originally discovered in the "Elgin Sandstones" along with *Telerpeton*, and it has since been found in strata of Triassic age in India. It was described by Professor Huxley as "a Saurian reptile about six feet long, remarkable for the flattened or slightly concave articular surfaces of the centra of its vertebræ, and for its well-developed costal system and fore and hind limbs; but more particularly characterised by its numerous series of subcylindrical palatal teeth." Upon the whole, Huxley concludes that *Hyperodapedon* is most nearly allied to the living *Sphenodon* (*Hatteria*) of New Zealand (fig. 554), upon the

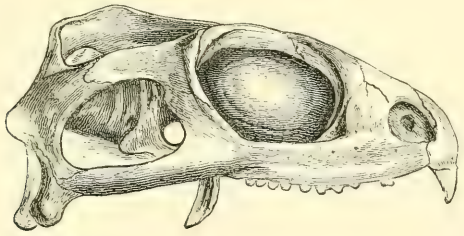

Fig. 554.—Side view of the skull of *Sphenodon* (*Hatteria*) *punctata*, the lower jaw being removed. (After Günther.)

grounds that both "have amphicœlous vertebræ (those of the ancient reptile being far less fish-like than those of the modern one, be it noted); both have beak-like præmaxillæ, not anchylosed together; both have the inferior zygoma

complete; both have similarly-formed lower jaws; in each a single row of teeth in the mandible bites between two rows of teeth fixed to a plate, which is formed by a union of the maxilla with the palatine bone—a structure which is quite anomalous amongst Lacertilians; and finally, in both, these teeth wear down to the bone of the jaw by masticatory attrition."

From its relations with the Triassic *Hyperodapedon*, as well as on account of its own peculiarities, the living *Sphenodon* possesses a special interest for the palæontologist. In this extraordinary form—the sole remaining representative of the Lacertilian family of the *Rhynchocephalia*—the vertebræ are amphicœlous, and some of the ribs bear "uncinate processes" similar to those of Birds. The quadrate bone is not movable, and is united by suture with the skull. The teeth are completely amalgamated by anchylosis with the jaws, and are developed in the mandible, præmaxillæ, and in a longitudinal series upon the palatine bones. The præmaxillary teeth are two in number, and are of large size and scalpriform in shape (fig. 554). The serrated edge of the mandible is received in the groove between the palatine teeth and the cutting edges of the maxillæ, the alveolar borders of which are hard and as highly polished as the teeth themselves, the function of which they discharge when the latter are ground down in advanced age.

The genus *Rhynchosaurus* is in a doubtful position, but may also conveniently be considered here. By Huxley its affinities are regarded as being Lacertilian, but by Owen it is looked upon as belonging to the *Anomodontia*, and as being most nearly allied to *Oudenodon*. In many points *Rhynchosaurus* approaches the existing Lizards, but its vertebræ are amphicœlous, and the structure of the mouth is quite unlike that of any living Lacertilian. The skull (fig. 555) is pyramidal, and the jaws do not exhibit any traces of teeth. If the mouth be really edentulous, then *Rhynchosaurus* should prob-

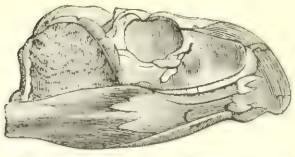

Fig. 555.—Skull of *Rhynchosaurus articeps*. (After Owen.) Trias.

ably be removed from the *Laçertilia;* but this point cannot in the meanwhile be definitely decided in the affirmative.

Amongst other Triassic, or supposed Triassic, Lacertilians, may be mentioned *Saurosternon* and *Pristerodon*, from strata believed to be of Triassic age in Africa, and *Centemodon* from deposits of the same age in North America.

In the Jurassic period the remains of Lacertilians are not very uncommon, but call for little special notice. Several forms of little importance have been described from the Middle Oolites. In the fresh-water strata of the Purbeck series (Upper Oolites), occur the remains which have been referred to the genera *Nuthetes*, *Macellodon*, *Saurillus*, and *Echinodon*. These are, perhaps, the first traces in the stratified series of remains, the affinities of which to the typical *Lacertidæ* cannot be disputed.

In the Cretaceous series occur the small Lizards which constitute the genera *Raphiosaurus*, *Coniosaurus*, and *Dolichosaurus*. Here also, and almost exclusively confined to strata of this age, occur the singular Lacertilians which form the group of the "Mosasauroids" (*Mosasauridæ*). These remarkable Reptiles were of gigantic size, *Mosasaurus princeps*

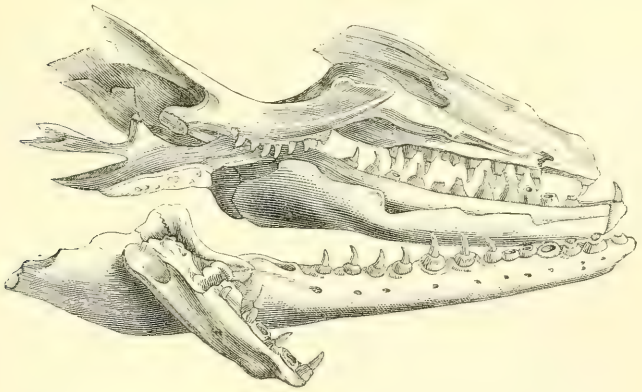

Fig. 556.—Skull of *Mosasaurus Camperi*, much reduced. Maestricht Chalk.

being believed to have attained the enormous length of not less than seventy-five feet. Originally referred to the *Cetacea* (Camper), and subsequently regarded as Crocodilian, the

Mosasauroids were first placed among the Lacertilians by Professor Owen, and the view entertained by this distinguished comparative anatomist of their real affinities is now generally accepted. Professor Cope, however, considers these Reptiles to form—under the name of *Pythonomorpha*—a group allied to the *Ophidia*.

The body in the Mosasauroids is greatly elongated, the vertebræ being procœlous, and sometimes provided with a zygosphene and zygantrum. The teeth (fig. 556) are long, pyramidal, and slightly curved; but they are anchylosed to the jaw, and are not sunk into distinct sockets, as in the living Crocodiles. The condition of the integument is unknown in many forms; but Marsh has recently shown that osseous dermal scutes are present in some forms (*e. g.*, *Holcodus*, *Leiodon*, and *Edestosaurus*), and we may reasonably infer the presence of a similar armature in other members of the group. It is not known, however, how much of the surface was thus protected, though it would appear that the head was certainly not defended by scutes. From the shortness of the humerus, and the indications that the vertebral column was unusually flexible, and that the tail was laterally compressed, it was early conjectured that the Mosasauroids were marine and aquatic in their habits. This conjecture has been raised to the rank of a certainty by the discovery that the fore and hind limbs of the Mosasauroids were in the form of fin-like paddles (fig. 557), like those of the Ichthyosaur and Plesiosaur, but having the digits distinct. There can therefore be no doubt that *Mosasaurus*—like the living *Amblyrhynchus*—was aquatic in its habits, and frequented the sea-shore, coming, in fact, only occasionally to the

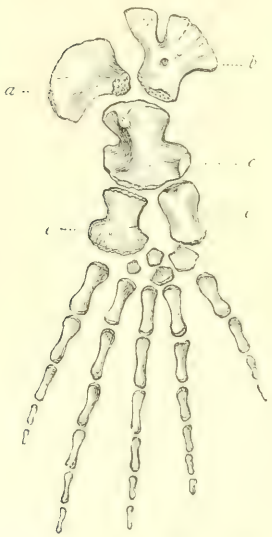

Fig. 557.—Right anterior paddle of *Lestosaurus simus*, one-twelfth of the natural size. (After Marsh.) *a*, Scapula; *b*, Coracoid; *c*, Humerus; *d*, Radius; *e*, Ulna.

land. The best-known genus is *Mosasaurus*, of which the most celebrated species is the *M. Camperi* (fig. 556) of the Maestricht Chalk. Other genera belonging to this group are *Leiodon*, *Tylosaurus*, *Lestosaurus*, *Clidastes*, &c. The entire group, so far as at present known, is confined to the Cretaceous rocks, and though represented in Europe, it seems to have had its maximum development in the North American area.

In the Tertiary rocks the remains of Lacertilians are not by any means unknown, but none of the forms of this period are sufficiently important to demand especial attention. Most of the Tertiary Lacertilians, however, are of small size, and appear to have been terrestrial in their habits, thus approximating to the typical existing Lizards. The most remarkable group of the Tertiary Lizards, however, is that of the *Glyptosauridæ* (*Glyptosaurus*, and *Orcosaurus*), comprising forms which are found in the Eocene Tertiary of North America, and have the anomalous character that the skin was furnished with ornamented osseous scutes. It is also worthy of notice that while the Tertiary Lizards are referable for the most part to actually existing groups, the recent genus *Chamæleo* seems to have been in existence as early as the Eocene.

Order IV. Crocodilia.—The last and highest order of the living *Reptilia* is that of the *Crocodilia*, including the living Crocodiles, Alligators, and Gavials, and characterised by the following peculiarities:—

The body is covered with an outer epidermic exoskeleton composed of horny scales, and an inner dermal exoskeleton consisting of transverse rows of squared bony plates or scutes, which may be confined to the dorsal surface alone, or may exist on the ventral surface as well, and which are disposed on the back of the neck into groups of different form and number in certain species. The bones of the skull and face are firmly united together, and the two halves or rami of the lower jaw are united in front by a suture. There is a single row of teeth, which are implanted in distinct sockets, and are hollowed at the base for the germs of the new teeth, by which they are successively pushed out and replaced during the life of the animal. *The centra of the dorsal*

vertebræ in all living Crocodilia are procœlous, or concave in front, but in the extinct forms they may be either amphicœlous (concave at both ends) or opisthocœlous (concave behind). The vertebral ends of the anterior trunk-ribs are bifurcate. There are two sacral vertebræ. The cervical vertebræ have small ribs; and there are generally false abdominal ribs produced by the ossification of the tendinous intersections of the *recti* muscles. There are no clavicles. *The heart consists of four completely distinct and separate cavities. All the four limbs are present, the anterior ones being pentadactylous, the posterior tetradactylous. All are oviparous.*

The chief points by which the Crocodiles are distinguished from their near allies the Lacertilians, are the possession of a partial bony dermal exoskeleton in addition to the ordinary epidermic covering of scales, the lodgment of the teeth in distinct sockets, and the fact that the mixture of venous and

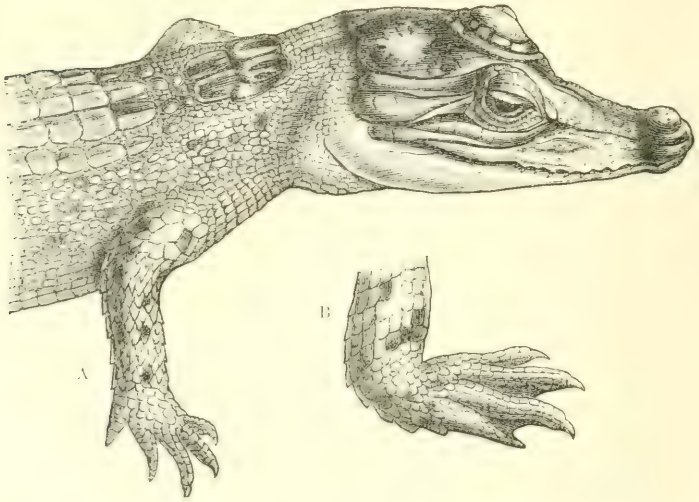

Fig. 558.—A, Head and anterior portion of the body of *Crocodilus pondicerianus*; B, Hind-foot of the same. (After Gunther.)

arterial blood, which is so characteristic of Reptiles, takes place, not in the heart itself, but in its immediate neighbourhood, by a communication between the pulmonary artery and aorta directly after their origin.

When the exoskeleton is complete (as in *Teleosaurus* and in Caiman), it consists of transverse rows of quadrate bony plates disposed so as to form a distinct dorsal and ventral shield, which are separated by soft skin in the region of the trunk, but become confluent in the tail. All the scutes of one row are united by suture, and successive rows usually movably overlap one another.

The order Crocodilia is divided by Owen into three sub-orders, termed *Procœlia*, *Amphicœlia*, and *Opisthocœlia*, according as the dorsal vertebræ are concave in front, concave at both ends, or concave behind.[1] The sub-order *Procœlia* comprises all the living forms—namely, the Crocodiles proper, the Alligators, and the Gavials. The first of these have the fourth tooth in the lower jaw (fig. 559) larger than the others, forming a canine tooth, which is received into a notch excavated in the alveolar border of the upper jaw, so that it is visible externally when the mouth is closed. In the Alligators (fig. 560), the fourth tooth in the lower jaw forms a canine which is received into a pit in the palatal surface of the upper jaw, where it is completely concealed when the mouth is shut. In the Gavials the snout is greatly prolonged,

[1] The following more elaborate classification of the recent and extinct *Crocodilia* has been proposed by Professor Huxley:—

I. Parasuchia, with no bony plates of the pterygoid or palatine bones to prolong the nasal passages; the Eustachian passages enclosed by bone; the centra of the vertebræ amphicœlian; the coracoid short and rounded; the ala of the ilium high, and its acetabular margin entire; and the ischium short dorso-ventrally and elongated longitudinally, with its acetabular portion resembling that of a Lizard.—Genera: *Stagonolepis, Belodon.*

II. Mesosuchia, with bony plates of the palatine bones prolonging the nasal passages, and giving rise to secondary posterior nares; a middle Eustachian canal included between the basioccipital and basisphenoid, and the lateral canals represented only by grooves; vertebral centra amphicœlian; coracoid elongated; ala of the ilium lower than in the preceding, higher than in the next sub-order, its acetabular margin nearly straight; ischium more elongated dorso-ventrally than in the preceding group, with its acetabular margin deeply notched. — Genera: *Steneosaurus, Pelagosaurus, Teleosaurus, Teleidosaurus, Metriorhynchus* (*Goniopholis? Pholidosaurus?*).

III. Eusuchia, with both pterygoid and palatine bones giving off plates which prolong the nasal passages; vertebral centra mostly procœlous; coracoid elongated; ala of the ilium very low in front, its acetabular margin deeply notched; ischium elongated dorso-ventrally, with its articular margin deeply excavated.—Genera: *Thoracosaurus, Holops,* and the recent forms.

and the teeth are pretty nearly equal in size and similar in form in the two jaws.

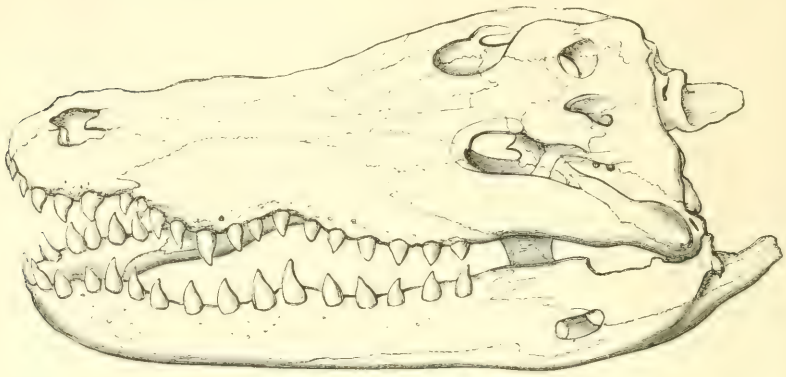

Fig. 559.—Skull of the Crocodile.

The first appearance of *Procœlian* Crocodiles, so far as known, is in the upper portion of the Cretaceous series of North America, where they are represented by the genera *Bottosaurus*, *Holops*, and *Thoracosaurus*, all of which are pe-

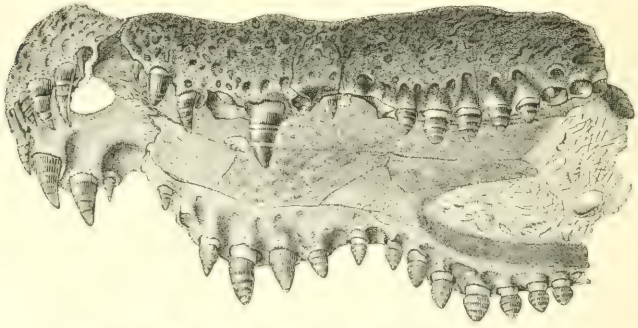

Fig. 560.—Upper jaw of Alligator. Eocene Tertiary, Isle of Wight.

culiar to this formation. In Europe, however, the earliest remains of Procœlian Crocodiles are from the Lower Tertiary rocks (Eocene). It is a curious fact that in the Eocene rocks of the south-west of England, there occur fossil remains of all the three living types of the *Crocodilia*—namely, the Gavials, true Crocodiles, and Alligators; though at the pres-

ent day these forms are all geographically restricted in their range, and are never all associated together. It is also a singular fact that the genus *Gavialis*, now entirely Asiatic in its distribution, should occur in the North American area in deposits as old as the Eocene Tertiary.

The *Amphicœlian* Crocodiles are characterised by their biconcave vertebræ, and are entirely extinct, being confined altogether to the Mesozoic period. The biconcave vertebræ show a decided approach to the structure of the backbone in fishes; and as the rocks in which they occur are mostly marine, there can be little doubt but that these Crocodiles were, in the majority of cases at any rate, inhabitants of the sea. Others, however, which are found in fresh-water deposits or estuarine accumulations, probably resembled the existing Crocodiles in principally frequenting rivers. From a palæontological point of view the Amphicœlian Crocodiles are much the most important group of the order *Crocodilia*, as they are, also, its most ancient representatives.

The earliest types of the *Amphicœlia*, and therefore of the order *Crocodilia*, are the *Stagonolepis* and *Belodon* of the Trias. The affinities of the former genus have been worked out by Prof. Huxley, who has shown that *Stagonolepis* resembled the existing Caimans in general form, but that it possessed the elongated skull of the Gavials. The body was protected by a ventral and dorsal series of bony, pitted scutes, but there were only two rows of the latter; and the teeth have obtusely-pointed crowns, which sometimes show signs of having been subjected to attrition. In *Belodon*, on the other hand, the teeth (fig. 561) are long, pointed, and conical, slightly curved, and longitudinally striated. The jaws were greatly elongated, as in the existing Gavials.

Fig. 561.—Tooth of *Belodon Carolinensis*. Trias. North America.

In the Jurassic series the remains of Amphicœlian Crocodiles are abundant, and belong to such genera as *Steneosaurus*, *Teleosaurus*, *Makrospondylus*, *Pelagosaurus*, *Metriorhynchus*, &c. The first two of the forms mentioned above are the most

important and the most widely distributed. Of these, *Teleosaurus* is a well-known Mesozoic type, represented by many Jurassic species, and having the jaws greatly elongated, and carrying numerous conical teeth, as in the living Gavials. The dermal scutes are large and exceptionally strong and solid. The Jurassic genus *Steneosaurus* (fig. 562) also comprises Jurassic Crocodilians, which, except for their amphicœlous vertebræ, have many points of resemblance to the existing Gavials.

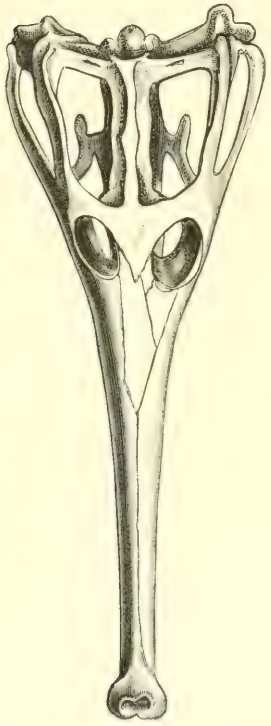

Fig. 562.—Skull of *Steneosaurus Heberti*, viewed from above. Jurassic. Actual length about three feet and a half. (After Morel de Glasville.)

In the Cretaceous rocks, lastly, and especially in the estuarine deposits of the Wealden, we have various types of Amphicœlian Crocodiles, such as *Goniopholis*, *Pholidosaurus*, and *Diplosaurus*. The genus *Hyposaurus* is found in the Cretaceous of North America, and its species resemble in form the modern Gavials.

We may briefly consider here a group of Reptiles which have been regarded as Crocodilian, but which are placed by Owen in a separate order under the name of *Thecodontia*, and which are looked upon by Huxley as being *Deinosaurian*. The "Thecodont" Reptiles are defined as follows: "Vertebral bodies biconcave; ribs of the trunk long and bent, the anterior ones with a bifurcate head; sacrum of three vertebræ; limbs ambulatory, femur with a third trochanter. Teeth with the crown more or less compressed, pointed, with trenchant and finely serrate margins, implanted in distinct sockets."—(Owen.)

Omitting *Belodon*, now generally regarded as Crocodilian, the Thecodont Reptiles are the *Thecodontosaurus* and *Palæosaurus* (fig. 563) of the Trias. These were orginally based

upon detached teeth found in a dolomitic conglomerate near Bristol, which has sometimes been supposed to be of Permian age, but which appears to be undoubtedly referable to the Trias. Teeth having the same generic characters have also been brought to light in the Triassic deposits of North America. In some respects the Thecodont Reptiles make an approach to the Lacertilians, while in others they approximate to the *Deinosauria*. Upon the whole, however, they would seem to be best regarded as an ancient group of Amphicœlian Crocodiles, distinguished by their compressed, trenchant, and serrated teeth.

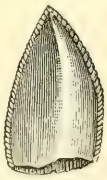

Fig. 563.—Tooth of *Palæosaurus platyodon*. Trias. Britain.

Lastly, the sub-order of the *Opisthocœlian* Crocodiles, including those forms in which the anterior trunk vertebræ are concave behind, is one which can be only provisionally retained. Professor Owen includes in this section the two genera *Streptospondylus* and *Cetiosaurus;* but the latter is referable to the *Deinosauria,* and will be treated of when that order is considered. The genus *Streptospondylus* has been founded on vertebræ obtained from the Oolitic and Wealden formations; but there are doubts as to the true position of the Reptile to which these belonged.

CHAPTER XXXV.

EXTINCT ORDERS OF REPTILES.

It remains now to consider briefly the leading characters of six wholly extinct orders of Reptiles, the peculiarities of which are very extraordinary, and are such as are exhibited by no living forms.

Order V. Ichthyopterygia, Owen (= *Ichthyosauria*, Huxley).—The gigantic Saurians forming this order were distinguished by the following characters:—

The body was fish-like, without any distinct neck, and probably covered with a smooth or wrinkled skin, no horny or bony exoskeleton having been ever discovered. The vertebræ were numerous, deeply biconcave or amphicœlous, and having the neural arches united to the centra by a distinct suture. The anterior trunk-ribs possess bifurcate heads. There is no sacrum, and no sternal ribs or sternum, but clavicles were present as well as an interclavicle (episternum); and false ribs were developed in the walls of the abdomen. The skull had enormous orbits separated by a septum, and an elongated snout. The eyeball was protected by a ring of bony plates in the sclerotic. The teeth were not lodged in distinct sockets, but in a common alveolar groove. The fore and hind limbs were converted into swimming-paddles, the ordinary number of digits (five) remaining recognisable, but the phalanges being greatly increased in number, and marginal ossicles being added as well. A vertical caudal fin was in all probability present.

The order *Ichthyopterygia* includes only the gigantic and fish-like *Ichthyosauri* (fig. 564), all exclusively Mesozoic,

and abounding in the Lias, Oolites, and Chalk, but especially characteristic of the Lias. As itself forming the order, the essential characters of *Ichthyosaurus* are those above given. In all the species of the genus, the head is of proportion-

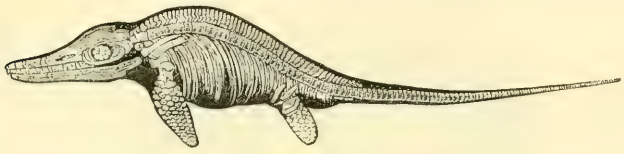

Fig. 564.—*Ichthyosaurus communis.* Lias.

ately gigantic size, not separated from the trunk by a distinct neck, and prolonged anteriorly into a huge snout, the jaws carrying a formidable array of conical teeth. The orbits are of immense size, and the small apertures of the nostrils are situated close beside them. The vertebral column is long, and there is a long series of ribs, extending from the neck to the tail, but none of them united in front with a sternum. The absence of a breast-bone, however, is compensated for by the development of a number of transverse curved bones, which strengthen the abdominal walls, and each of which consists of a median section and of three or more overlapping pieces on each side. The vertebral centra are deeply amphicœlous, the transverse and articular processes being rudimentary, while the neural arches have for the most part only a cartilaginous connection with the bodies of their respective vertebræ; so that the latter are commonly found in a fossil condition in a perfectly detached state. Beneath the caudal vertebræ are placed V-shaped "chevron-bones."

The pectoral arch (fig. 565, A) consists of a T-shaped interclavicle, with a clavicle, coracoid, and scapula on each side, the coracoids being of large size. The pelvic arch (fig. 565, B)—there being no sacrum—is not directly connected with the spine; but the pubic and ischial bones unite by symphysis. Both the pectoral and pelvic limbs are in the form of paddles, the former being placed just behind the head, and being generally much larger than the latter. Each paddle (fig. 565, A) is composed of numerous

short polygonal bones, arranged in generally five longitudinal and closely-approximated rows, the apparent number of the digits being increased by the development of supernumerary rows of "marginal" ossicles on both sides of the paddle.

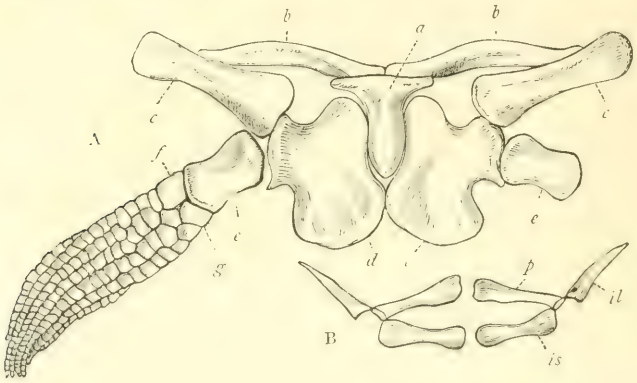

Fig. 565. — A, Pectoral arch and fore-limbs of *Ichthyosaurus*: *a*, Interclavicle; *b*, *b*, Clavicles; *c*, *c*, Scapulæ; *d*, *d*, Coracoids; *e*, Humerus; *f*, Radius; *g*, Ulna. (Somewhat altered from Huxley.) B, Pelvis of *Ichthyosaurus*: *p*, Pubis; *il*, Ilium; *is*, Ischium.

As regards their distribution in time, the Ichthyosaurs, as before said, are not known with certainty to have existed in rocks earlier than the Lias or later than the Chalk; and though abundant in the European area, no unequivocal remains of the genus have yet been detected in the corresponding formations in North America.[1] In the year 1861, however, Professor Marsh discovered in the Coal-measures of Nova Scotia two large amphicœlous vertebræ, which he described under the name of *Eosaurus Acadiensis*. These vertebræ (fig. 566) are of very large size (about two and a half inches in diameter), and they are deeply excavated at both ends. They are regarded by Professor Marsh as indicating

[1] Since these sheets have been in the hands of the printer, Professor Marsh has described the remains of a large Saurian from the Jurassic rocks of the Rocky Mountains, which agrees with *Ichthyosaurus* in the general structure of the skeleton, but in which *there are no teeth*. The length of this singular Reptile is about eight or nine feet, the vertebræ are deeply biconcave, there are eight sclerotic plates, and the orbits are very large. It has been named *Sauranodon natans*, and Professor Marsh regards it as the type of a new order of Reptiles (*Sauranodonta*).

the existence in the later Carboniferous period of a gigantic reptile allied to *Ichthyosaurus*. If this view were confirmed, it would carry back the range of the Ichthyosaurs to the Carboniferous; but it is believed by Huxley that these remains may truly belong to some large Labyrinthodont.

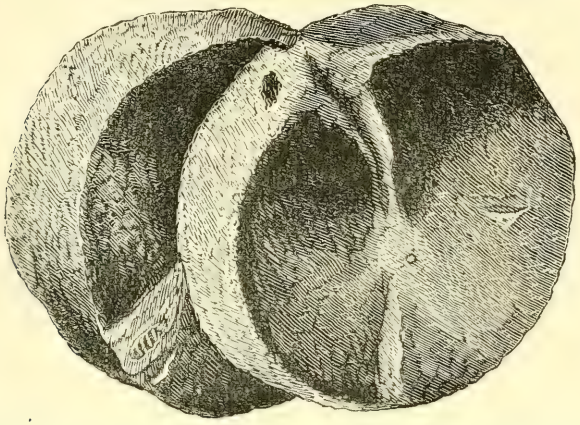

Fig. 566.—Two vertebræ of *Eosaurus Acadiensis* (Marsh). Coal-measures of Nova Scotia. (After Dawson.)

As regards their habits, there is no doubt whatever but that the *Ichthyosauri* were essentially marine animals, and they have been often included with the next order (*Sauropterygia*) in a common group, under the name of *Enaliosauria* or Sea-lizards.

In the biconcave vertebræ and probable presence of a vertical tail-fin, the *Ichthyosaurus* approaches the true Fishes. There is, however, no doubt as to the fact that the animal was strictly an air-breather, and its reptilian characters cannot be questioned, at the same time that the conformation of the limbs is decidedly Cetacean in many respects. Much has been gathered from various sources as to the habits of the *Ichthyosaurus*, and its history is one of great interest. From the researches of Buckland, Conybeare, and Owen, the following facts appear to be pretty well established: That the *Ichthyosauri* kept chiefly to open waters may be inferred from their strong and well-developed swimming-apparatus. That they occasionally had recourse to the shore, and crawled

upon the beach, may be safely concluded from the presence of a strong and well-developed bony arch, supporting the fore-limbs, and closely resembling in structure the scapular arch of the *Ornithorhynchus* or Duck-mole of Australia. That they lived in stormy seas, or were in the habit of diving to considerable depths, is shown by the presence of a ring of bony plates in the sclerotic, protecting the eye from injury or pressure. That they possessed extraordinary powers of vision, especially in the dusk, is certain from the size of the pupil, and from the enormous width of the orbits. That they were carnivorous and predatory in the highest degree is shown by the wide mouth, the long jaws, and the numerous, powerful, and pointed teeth. This is proved, also, by an examination of their petrified droppings, which are known to geologists as "coprolites," and which contain numerous fragments of the scales and bones of the Ganoid fishes which inhabited the same seas.

Order VI. Sauropterygia, Owen (= *Plesiosauria*, Huxley).—This order of extinct reptiles, of which the well-known *Plesiosaurus* may be taken as the type, is characterised by the following peculiarities:—

The body, as far as is known, was naked, and not furnished with any horny or bony exoskeleton. The bodies of the vertebræ were either flat or only slightly cupped at each end, and the neural arches were anchylosed with the centra, and did not remain distinct during life. The transverse processes of the vertebræ were long, and the anterior trunk-ribs had simple, not bifurcate, heads. No sternum or sternal ribs are known to have existed, but there were false abdominal ribs. The neck (fig. 567) *in most was greatly elongated, and composed of numerous vertebræ. The sacrum was composed of two vertebræ. The orbits were of large size, and there was a long snout, as in the Ichthyosauri, but there was no circle of bony plates in the sclerotic. The limbs agree with those of the Ichthyosauri in being in the form of swimming-paddles* (fig. 568), *but differ in not possessing any supernumerary marginal ossicles. The pectoral arch consisted of a large coracoid and scapula on each side, while clavicles and an interclavicle were sometimes present, but at other times apparently wanting. The teeth were simple,*

and were inserted into distinct sockets, and not lodged in a common groove.

The most familiar and typical member of the *Sauropterygia* is the genus *Plesiosaurus* (fig. 567), comprising gigantic

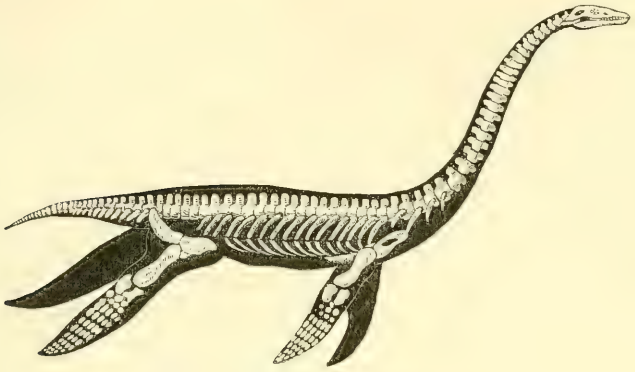

Fig. 567.—*Plesiosaurus dolichodeirus.* Lias.

marine reptiles, chiefly characteristic of the Lias and Oolites. In its general structure, there are various points in which *Plesiosaurus* makes a near approach to *Ichthyosaurus*, while, on the other hand, there are equally striking points of difference between the two genera. Thus, in both, the pelvic and pectoral limbs have the digits enveloped in the integument, and the fore-arm and arm much shortened, these organs thus being reduced to the condition of efficient swimming-paddles or "flippers." In both the skin is naked, and the snout is prolonged, the jaws being furnished with numerous teeth. In both there is an absence of a sternum and of sternal ribs, but the walls of the abdomen are strengthened by supplementary ossifications, each consisting of a central and of lateral overlapping pieces. On the other hand, the head in *Plesiosaurus* is comparatively small, and the neck is quite disproportionately elongated, while the tail is short. The orbits are not ex-

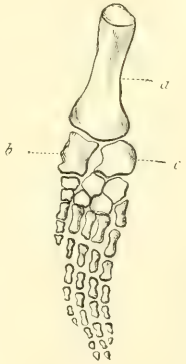

Fig. 568.—Left fore-paddle of *Plesiosaurus*. *a*, Humerus; *b*, Radius; *c*, Ulna.

ceptionally large, and though the nostrils are placed close beside the orbits, as in *Ichthyosaurus*, there is no sclerotic ring. The teeth are conical and pointed, with longitudinally striated crowns, but each is sunk in an independent socket. The vertebral centra are only slightly biconcave, and the neutral arches are united with them by osseous junction. The pectoral arch consists of a large coracoid and scapula on each side, but clavicles and interclavicle may be apparently wanting. The paddles are proportionately longer than those of *Ichthyosaurus*, and though formed on the same plan, consist only of the five digits, without marginal ossicles in addition. The pelvic arch is well developed, and there is a sacrum of two vertebræ. As regards the habits of the *Plesiosaurus*, Dr Conybeare arrives at the following conclusions: "That it was aquatic is evident from the form of its paddles; that it was marine is almost equally so from the remains with which it is universally associated; that it may have occasionally visited the shore, the resemblance of its extremities to those of the Turtles may lead us to conjecture; its movements, however, must have been very awkward on land; and its long neck must have impeded its progress through the water, presenting a striking contrast to the organisation which so admirably fits the *Ichthyosaurus* to cut through the waves." As its respiratory organs were such that it must of necessity have required to obtain air frequently, we may conclude "that it swam upon or near the surface, arching back its long neck like a swan, and occasionally darting it down at the fish which happened to float within its reach. It may perhaps have lurked in shoal water along the coast, concealed amongst the sea-weed; and raising its nostrils to a level with the surface from a considerable depth, may have found a secure retreat from the assaults of powerful enemies; while the length and flexibility of its neck may have compensated for the want of strength in its jaws, and its incapacity for swift motion through the water."

The geological range of the *Plesiosaurus* is from the Lias to the Chalk inclusive, and specimens have been found indicating a length of from eighteen to twenty feet. About twenty species of *Plesiosaurus* have been described in all.

Of the remaining genera of the *Sauropterygia, Nothosaurus, Simosaurus, Placodus, Pistosaurus,* and *Conchiosaurus* are Triassic. In *Nothosaurus* (fig. 569) the neck is long, and com-

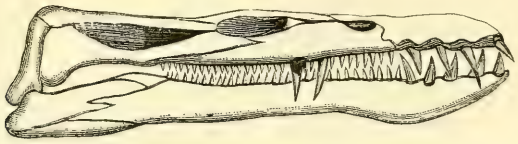

Fig. 569.—Skull of *Nothosaurus mirabilis,* reduced size. Trias (*Muschelkalk*), Germany.

posed of at least twenty vertebræ. The dorsal vertebræ are biconcave, and the limbs are converted into swimming-paddles. The teeth are numerous and conical, and are implanted into distinct sockets. Several species are known, all Triassic, and especially characteristic of the Muschelkalk. *Simosaurus* had a large head with enormous orbits, and teeth sunk into distinct sockets. This genus is exclusively confined to the Muschelkalk. In *Placodus* (fig. 570), the teeth are in distinct sockets, and resemble those of many fishes in being rounded and obtuse, forming broad crushing plates adapted for the comminution of shell-fish. The upper jaw contains a double series of these teeth, an outer or maxillary series, and an internal or palatal series; but the under jaw has only a single row of teeth.

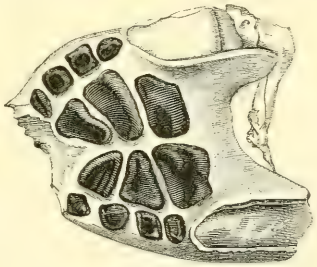

Fig. 570.—Under surface of the upper jaw in *Placodus gigas.* Muschelkalk.

In the Jurassic period the principal genus is *Pliosaurus,* comprising huge reptiles, allied to the *Plesiosaurus* in their fin-like paddles, but having an enormous head supported upon a short neck. The teeth are simple and conical, and in large specimens attain a great size. *Pliosaurus* is confined to the Middle and Upper Oolites. Other Jurassic genera of *Sauropterygia* are known, but they present no features of special importance. In the Cretaceous period, lastly, the principal European representative of this order is *Plesiosaurus* itself; whereas in deposits of corresponding age in North America,

we meet with types such as *Pliosaurus* and the related genera *Discosaurus* (or *Elasmosaurus*), and *Cimoliosaurus*.

Order VII. Anomodontia.—The members of this order are especially characterised by *the structure of the mouth, the jaws being converted into a kind of beak, which was probably sheathed in horn, and resembled the jaws of a Turtle. Sometimes the mouth appears to have been wholly destitute of teeth, but in other cases there was a single pair of teeth implanted in the upper jaw, growing from persistent pulps, and assuming the character of great tusks. The dorsal vertebræ are biconcave, and the anterior trunk-ribs have bifurcate heads. The sacrum is large, composed of several vertebræ. The animal seems to have been organised for terrestrial progression, the pectoral and pelvic arches being strong, and the limbs well developed.*

According to Prof. Huxley, the form of the body in the Anomodonts was probably like that of the Lizards; but the vertebræ are of a Crocodilian type, and though the skull exhibits Lacertilian characters, the jaws remind us more of the Chelonians.

By Owen the genera *Dicynodon, Oudenodon,* and *Rhynchosaurus* are included in this order; but the last of these is regarded by Huxley as a Lacertilian. In *Dicynodon* (fig. 571, A), the anterior portions of the jaws appear to have been altogether toothless; and they form a kind of beak, which was probably sheathed in horn. The lower jaw has no teeth; but each superior maxilla carries an enormous tusk-like tooth growing from a persistent pulp. These great canines pass downwards outside the forepart of the lower jaw, about one-third of their length being concealed within their sockets. In minute structure they consist of simple, compact, non-vascular dentine, with a thin layer of enamel; and their points are simply conical and not bevelled or chisel-shaped. Probably they were used solely as weapons of offence and defence. In *Oudenodon,* on the other hand, the mouth is beak-shaped (fig. 571, B), and seems to have possessed no teeth of any kind. *Dicynodon* and *Oudenodon* are known only from strata of supposed Triassic age in India and South Africa.

Order VIII. Pterosauria (*Ornithosauria*, Seeley).—This

order includes a group of extraordinary flying Reptiles, all belonging to the Mesozoic epoch, and exhibiting in many respects a very extraordinary combination of characters.

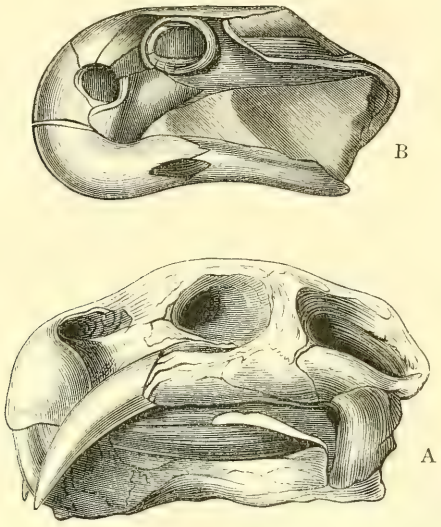

Fig. 571.—A, Skull of *Dicynodon lacerticeps*, showing the maxillary tusk; B, Skull of *Oudenodon Bainii*. From the Trias of South Africa. (After Owen.)

The most familiar members of the order are the so-called "Pterodactyles," and the following are the characters of the order :—

No exoskeleton is known to have existed. The dorsal vertebræ are procœlous, and the anterior trunk-ribs are double-headed. There is a broad sternum with a median ridge or keel, and ossified sternal ribs. The jaws were generally armed with teeth, and these were implanted in distinct sockets. In some forms (*Rhamphorhynchus*) there appear to have been no teeth in the anterior portion of the jaws, and these parts seem to have been sheathed in horn, so as to constitute a kind of beak. In the genus *Pteranodon*, from the Cretaceous rocks of North America, comprising gigantic examples of the order, the jaws are completely destitute of teeth, and appear to have been encased in a horny beak.

A ring of bony plates occurs in the sclerotic coat of the eye.

The pectoral arch consists of a scapula and distinct coracoid bone, articulating with the sternum as in Birds, but no clavicles have hitherto been discovered. The fore-limb (fig. 572) *consists of a humerus, ulna and radius, carpus, and hand of four fingers, of which the inner three are short and unguiculate, whilst the outermost is clawless and is enormously elongated. Between this immensely-lengthened finger, the side of the body, and the comparatively small hind-limb, there must have been supported an expanded flying-membrane, or "patagium," which the animal must have been able to employ as a wing, much as the Bats of the present day. Lastly, most of the bones were "pneumatic"—that is to say, were hollow and filled with air.*

While the above are the general characters of the *Pterosauria*, there are various points in the anatomy of these

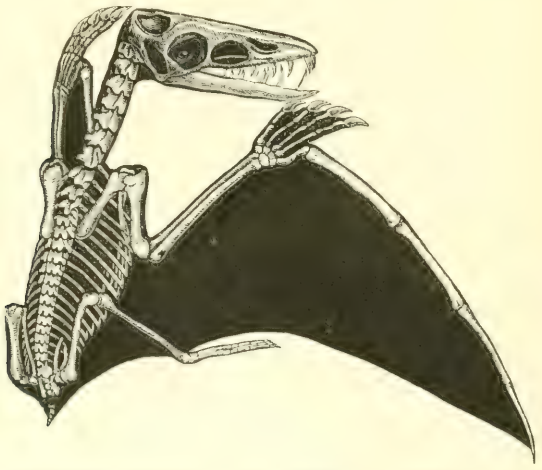

Fig. 572.—*Pterodactylus crassirostris.* From the Lithographic Slates of Solenhofen (Upper Oolite). In accordance with the view originally entertained, the digits of the hand are here erroneously represented as five instead of four in number.

singular Reptiles which may be more closely considered. The head in all the Pterosaurs is elongated and bird-like, the cranial bones becoming early anchylosed, the general fabric of the skull being unusually light, and the orbits being exceptionally large. The occipital condyle is placed on the inferior aspect of the skull, instead of being posterior, thus indicating that the animal was in the habit of standing in an

erect posture. The vertebral column is divisible into its usual regions, the cervical region being long, and composed of large and strong vertebræ, which do not carry ribs. In the procœlous form of the dorsal vertebræ, the Pterosaurs agree with many Reptiles, and differ from all known Birds. The sacrum consists of from three to six vertebræ, and the tail is very short in *Pterodactylus*, and very long in *Dimorphodon*. It is, however, in the structure of the limbs and their supporting arches that the Pterosaurs exhibit some of their most remarkable characters. The pectoral arch is in many respects very ornithic in its character, with long and slender scapulæ and distinct coracoids, but no clavicles are known. The sternum (fig. 573, B) is of large size and broad form, and resembles that of Birds in having a median ridge or keel. Ossified costal cartilages or "sternal ribs" connect the breast-bone with the ribs, as in Birds; but there is the Reptilian character that splint-like abdominal ribs are present. The brachium and antibrachium present no peculiarities of special note. The hand consists of four digits, of which, in accordance with the views generally entertained, the innermost or thumb consists of two phalanges, the second or index has three phalanges, and the third or middle finger has four phalanges. All these three digits, also, are clawed. The fourth digit or ring-finger, on the other hand, is greatly elongated, and is clawless (figs. 573, 574). It carries the flying membrane, and consists usually of four phalanges, though it has only two phalanges in *Ornithopterus*. It should be mentioned that this elongated digit is sometimes regarded as being really the index.

As regards the hind-limb, the pelvis is very small; the ilia are produced both in front of and behind the acetabulum, as in Birds; and the foot generally consists of five digits, of which four have sharp claws, while the "little toe" may either be rudimentary or longer than the other toes, serving in the latter case to assist in the expansion of the flying-membrane (fig. 574, *p*). According to Prof. Seeley, the lower end of the tibia is really formed by anchylosis of the true tibia with the proximal tarsal bone, as in Birds.

With regard to the affinities of the *Pterosauria*, and their precise systematic position, scientific opinion is still not ab-

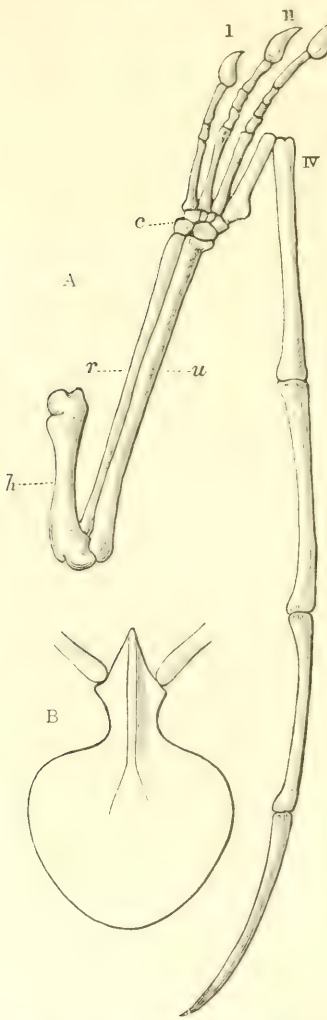

Fig. 573.—A, Fore-limb of *Pterodactylus crassirostris*: *h*, Humerus; *r*, Radius; *u*, Ulna; *c*, Carpus; i, ii, iii, iv, Digits. B, Sternum of Pterodactyle, showing the median keel.

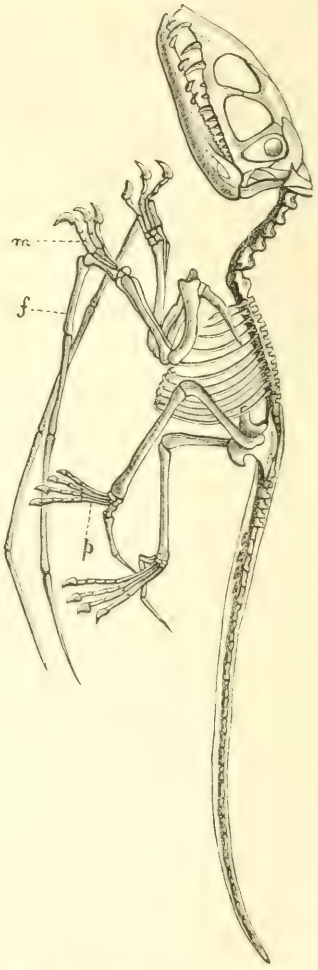

Fig. 574. — Skeleton of *Dimorphodon macronyx*, reduced in size and restored (after Owen). *m*, Hand; *f*, Elongated finger carrying the patagium; *p*, Foot. Lias.

solutely unanimous. That they possessed the power of true

flight is conclusively shown by the presence of a median keel upon the sternum, proving the existence of unusually-developed pectoral muscles; by the articulation of the coracoid bones with the top of the sternum, providing a fixed point or fulcrum for the action of the pectoral muscles; and, lastly, by the existence of air-cavities in the bones, this being a feature otherwise peculiar to the true Birds. The apparatus, however, of flight was not a "wing," as in Birds, but a flying-membrane, very similar in its mode of action to the patagium of the Mammalian order of the Bats. The patagium of the Bats, however, differs from that of the Pterodactyles in being supported by the greatly-elongated fingers, whereas in the latter it is only the outermost finger which is thus lengthened out. Moreover, to mention one other point of difference only, the Pterodactyles possess pneumatic foramina in some of the bones, indicating a structure of the breathing-organs similar to that now found in the Birds, and wholly unknown amongst the Mammals. The only question, then, at the present day is as to whether the Pterosaurs are most nearly related to the Reptiles or to the Birds; and it is amongst the former that they are most generally placed. No known Reptile has any power of sustaining itself in the air in any manner which can justifiably be compared with the flight of Birds; since the little Flying Dragons (*Draco*) simply take leaps from tree to tree by means of laterally-extended folds of skin. No known Reptile, further, has pneumatic bones; and there are other points of difference which separate the Pterosaurs from all the typical Reptiles. Still, the general structure of the skeleton is distinctly Reptilian; and the absence of a non-conducting covering of feathers to the skin would prove that the animal must have been cold-blooded. The structure of the hand, further, though abnormal, is exceedingly unlike that which obtains in Birds. Lastly, it is only in certain very aberrant Cretaceous Birds that we meet with teeth in the jaws. These considerations would seem to justify the reference of the *Pterosauria* to the *Reptilia*, of which they form an altogether peculiar order. Prof. Seeley, however, regards the Pterosaurs as forming a distinct class which he

terms *Ornithosauria,* and which he looks upon as most nearly related to, but coequal with, the class *Aves.* The chief grounds for this conclusion, apart from subordinate skeletal peculiarities, are that the Pterosaurs possessed a brain of an ornithic type of structure, and that some of their bones were pneumatic.

The *Pterosauria* are exclusively Mesozoic, being found from the Lower Lias to the Middle Chalk inclusive, the Lithographic Slate of Solenhofen (Upper Oolite) being particularly rich in their remains. Most of them appear to have attained no very great size, but the remains of forms from the Cretaceous rocks have been considered to indicate animals with more than twenty feet expanse of wing, counting from tip to tip.

The chief generic types of the *Pterosauria* are characterised as follows:—

1. *Pterodactylus* (fig. 572), comprising forms with four phalanges in the wing-finger, the jaws provided with teeth to their extremities, and all the teeth being long and slender. The tail is short and movable.

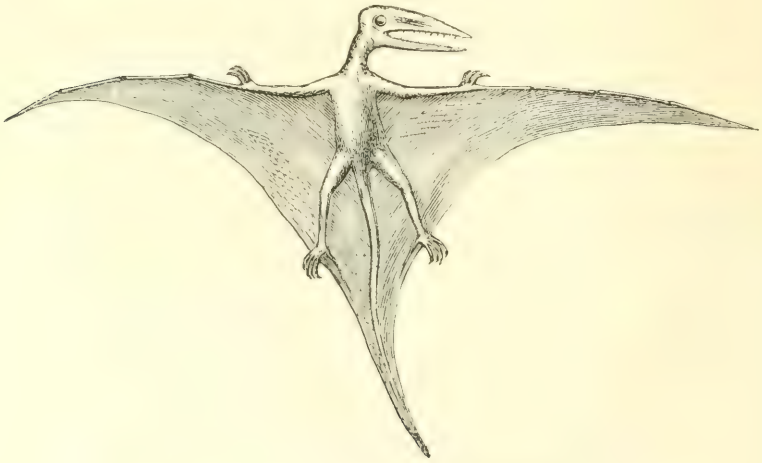

Fig. 575.—Restoration of *Dimorphodon macronyx.* (After Owen.)

2. *Dimorphodon* (figs. 574 and 575), comprising forms in which the wing-finger has four phalanges, and the jaws

are toothed; but the anterior teeth are large and pointed, and the posterior teeth are small and lancet-shaped. The tail is extremely long and movable. This genus is only known to occur in the Lias.

3. *Rhamphorhynchus*, comprising forms in which there are four joints to the wing-finger; but the front portion of both jaws is edentulous, and may have formed a horny beak, teeth being developed only in the hinder portion of the jaws. The tail is very long. The genus seems to be confined to the Jurassic rocks.

4. *Pteranodon*, comprising forms which appear to have the general structure of *Pterodactylus*, but the jaws are wholly destitute of teeth, and were probably ensheathed in horn. The scapulæ and coracoids are anchylosed, and the proximal ends of the scapulæ apparently show the unique character of being articulated to the neural spine of one of the dorsal vertebræ. The tail is short and slender. *Nyctisaurus* resembles the preceding in having edentulous jaws, but the scapula is not anchylosed with the coracoid, nor articulated with a vertebra. These two genera comprise gigantic forms of *Pterosauria* from the Cretaceous deposits of North America; and Prof. Marsh, to whom we owe a knowledge of their characters, regards them as forming a distinct section (*Pteranodontia*) of the order.

5. *Ornithopterus*, comprising forms in which the wing-finger has only two phalanges. This genus is only imperfectly known, and may possibly be really referable to the Birds.

Order IX. Deinosauria (*Ornithoscelida*, Huxley). — The next order of the Reptiles is that of the *Deinosauria*, comprising a group of very remarkable extinct forms, which are in some respects intermediate in their characters between the Cursorial birds and the typical Reptiles; whilst they have been supposed to have affinities to the Pachydermatous Mammals. Most of the *Deinosauria* were of gigantic size, and the order is defined by the following characters:—

The skin was sometimes naked, sometimes furnished with a well-developed exoskeleton, consisting of bony shields, much resembling those of the Crocodiles. A few of the anterior vertebræ were opisthocœlous, the remainder having flat or slightly

biconcave bodies. The anterior trunk-ribs were double-headed. The teeth were confined to the jaws and implanted in distinct sockets. There were always two pairs of limbs, and these were strong, furnished with claws, and adapted for terrestrial progression. In some cases the fore-limbs were very small in proportion to the size of the hind-limbs. No clavicles have been discovered.

The teeth are sometimes implanted in distinct sockets, and they are never anchylosed with the jaws. The ischium and pubes are much elongated; the inner wall of the acetabulum is formed by membrane; the tibia has its proximal end prolonged anteriorly into a strong "cnemial crest," as in the wading or swimming birds; and the astragalus is bird-like (Huxley).

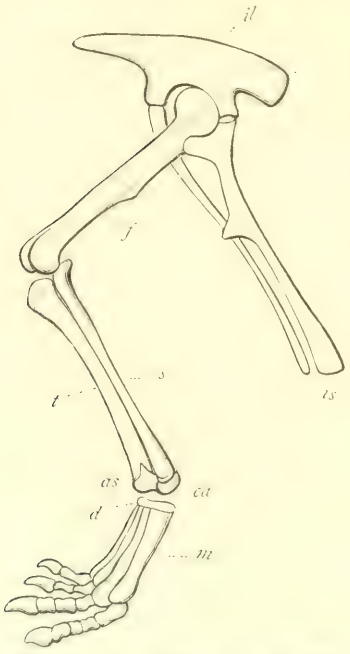

Fig. 576.—Leg of Deinosaur. *il*, Ilium; *is*, Ischium; *f*, Femur; *t*, Tibia; *s*, Fibula; *as*, Astragalus; *ca*, Calcaneum; *m*, Metatarsus. (After Huxley.)

The most remarkable points in the organisation of the *Deinosauria* are connected with the structure of the pelvis and hind-limb, the characters of which, as pointed out by Huxley, approximate to those of the same parts in the Birds, and especially in the Struthious Birds. This approximation is especially seen in the prolongation of the ilium in front of the acetabulum (fig. 576), the elongation and slenderness of form of the ischium, and the slenderness of the pubes. The astragalus is like that of a bird, and in some cases appears to have become anchylosed with the distal end of the tibia. Generally, however, the astragalus remains distinct, but even in this case the ankle-joint is placed between the astragalus and the distal portion of the tarsus. The metatarsal bones

also remain distinct, and are not anchylosed with any of the tarsal bones to form a "tarso-metatarsus."

The *Deinosauria* are exclusively Mesozoic, ranging from the Triassic to the Cretaceous formation, but abounding especially in the Oolitic and the earlier portion of the Cretaceous period. By Professor Huxley the "Thecodont" Reptiles are regarded as belonging here, as has been already remarked.

The number of known Deinosaurian Reptiles is already extremely large, but as many are only very imperfectly understood, it will be sufficient here to briefly notice a few of the more important or more interesting types. The number of genera known in the Trias (such as *Teratosaurus, Amphisaurus, Clepsysaurus, Bathygnathus,* &c.) is not very large, but even at this early period the order seems to have had a very wide distribution.

In the Jurassic and Cretaceous periods the order underwent an immense development, and is represented by numerous genera, such as *Iguanodon, Hypsilophodon, Laosaurus, Hadrosaurus, Cionodon, Poikilopleuron, Hylæosaurus, Polacanthus, Acanthopholis, Cetiosaurus, Titanosaurus, Megalosaurus, Lælaps, Compsognathus, Chondrosteosaurus,* &c. Of the above the most important types are *Iguanodon, Hylæosaurus, Megalosaurus, Cetiosaurus, Compsognathus,* and *Chondrosteosaurus.*

The *Iguanodon* is mainly, but not exclusively, Cretaceous, being especially characteristic of the great delta-deposit of the Wealden. The length of the *Iguanodon* has been estimated as being probably from fifty to sixty feet, and from the close resemblance of its teeth to those of the living Iguanas, there is little doubt that it was herbivorous and not carnivorous. The femur of a large *Iguanodon* measures from four to five feet in length, with a circumference of twenty-two inches in its smallest part. From the disproportionately small size of the fore-limbs, and from the occurrence of *pairs* of gigantic three-toed footsteps in the same beds, it has been concluded, with much probability, that *Iguanodon,* in spite of its enormous bulk, must have walked temporarily or permanently upon its hind-legs, thus coming to present a most marked and striking affinity to the Birds.

The teeth of *Iguanodon* (fig. 577) present a singularly close resemblance in shape to those of the comparatively pigmy Iguanas of the present day. Their crown is obtusely subtriangular, with longitudinal ridges, and having the surface

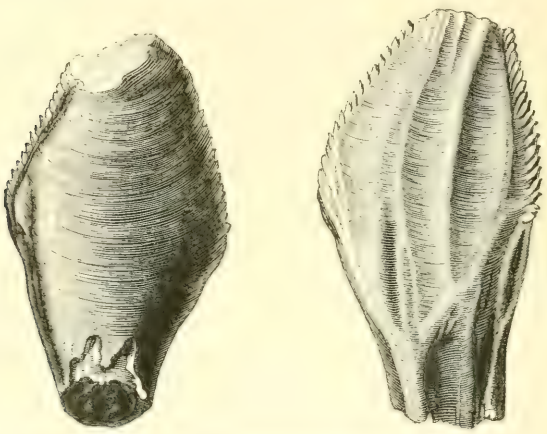

Fig. 577.—Teeth of *Iguanodon Mantellii*. Wealden.

of the enamel crenated on one or both sides. They present the extraordinary feature that the crown became worn down flat by mastication, showing that *Iguanodon* employed the teeth in the actual trituration of the vegetable matter on which it fed. The front portion of the jaws seems to have been toothless and beak-like, and the symphysis of the mandible is hollowed out above; the purpose served by this, according to the views of Professor Owen, being to facilitate the easy protrusion and retraction of a long muscular and prehensile tongue, employed by the animal in stripping off the foliage of trees. In the Cretaceous deposits of North America the genus *Iguanodon* is represented by the nearly-allied *Hadrosaurus*. *Iguanodon* is not known to have possessed any exoskeletal structures capable of preservation in the fossil state; but the *Hylæosaurus* of the Wealden possessed bony dermal scutes, prolonged along the middle line of the back into a row of enormous spines.

The gigantic *Cetiosaurus* of the Oolitic and Cretaceous rocks was originally placed amongst the *Crocodilia;* but the

researches of Professor Phillips have shown that it belongs really to the *Deinosauria*. Having obtained a magnificent series of remains of this reptile, Professor Phillips has been able to determine many very interesting points as to the anatomy and habits of this colossal animal, the total length of which he estimates as being probably not less than sixty or seventy feet. As to its mode of life, this accomplished writer remarks :—

"Probably when 'standing at ease' not less than ten feet in height, and of a bulk in proportion, this creature was unmatched in magnitude and physical strength by any of the largest inhabitants of the Mesozoic land or sea. Did it live in the sea, in fresh waters, or on the land? This question cannot be answered, as in the case of Ichthyosaurus, by appeal to the accompanying organic remains; for some of the bones lie in marine deposits, others in situations marked by estuarine conditions, and, out of the Oxfordshire district, in Sussex, in fluviatile accumulations. Was it fitted to live exclusively in water? Such an idea was at one time entertained, in consequence of the biconcave character of the caudal vertebræ, and it is often suggested by the mere magnitude of the creature, which would seem to have an easier life while floating in water, than when painfully lifting its huge bulk, and moving with slow steps along the ground. But neither of these arguments is valid. The ancient earth was trodden by larger quadrupeds than our elephant; and the biconcave character of vertebræ, which is not uniform along the column in Cetiosaurus, is perhaps as much a character of a geological period as of a mechanical function of life. Good evidence of continual life in water is yielded in the case of Ichthyosaurus, and other Enaliosaurs, by the articulating surfaces of their limb-bones, for these, all of them, to the last phalanx, have that slight and indefinite adjustment of the bones, with much intervening cartilage, which fits the leg to be both a flexible and forcible instrument of natation, much superior to the ordinary oar-blade of the boatman. On the contrary, in Cetiosaur, as well as in Megalosaur and Iguanodon, all the articulations are definite, and made so as to correspond to determinate movements in particular direc-

tions, and these are such as to be suited for walking. In particular, the femur, by its head projecting freely from the acetabulum, seems to claim a movement of free stepping more parallel to the line of the body, and more approaching to the vertical than the sprawling gait of the crocodile. The large claws concur in this indication of terrestrial habits. But, on the other hand, these characters are not contrary to the belief that the animal may have been amphibious; and the great vertical height of the anterior part of the tail seems to support this explanation, but it does not go further. For the later caudal vertebræ, instead of being much compressed, as in Teleosaurus, are nearly circular in the cross section, and are interlocked by posterior zygapophyses, extended over half or the whole length of a vertebræ. We have therefore a marsh-loving or river-side animal, dwelling amidst filicine, cycadaceous, and coniferous shrubs and trees full of insects and small mammalia. What was its usual diet? If *ex ungue leonem*, surely *ex dente cibum*. We have indeed but one tooth, and that small and incomplete. It resembles more the tooth of Iguanodon than that of any other reptile; and for this reason it seems probable that the animal was nourished by similar vegetable food which abounded in the vicinity, and was not obliged to contend with Megalosaurus for a scanty supply of more stimulating diet."

Colossal as are the dimensions of *Cetiosaurus*, they appear to have been exceeded by species of the genus *Atlantosaurus* (*Titanosaurus*). Thus *A. montanus*, from the Wealden of Colorado, according to Prof. Marsh, "is by far the largest land-animal yet discovered; its dimensions being greater than was supposed possible in an animal that lived and moved upon the land. It was some fifty or sixty feet in length, and, when erect, at least thirty feet in height. It doubtless fed upon the foliage of the mountain forests, portions of which are preserved with its remains."

Megalosaurus is a gigantic Oolitic Reptile, which occurs also in the Cretaceous series (Weald Clay). Its length has been estimated at between forty and fifty feet, the femur and tibia each measuring about three feet in length. As the head of the femur is set on nearly at right angles with the

shaft, whilst all the long bones contain large medullary cavities, there can be no doubt but that *Megalosaurus* was terrestrial in its habits. That it was carnivorous and destructive in the highest degree is shown by the powerful, pointed, and trenchant teeth.

The teeth in *Megalosaurus* (fig. 578) are conical, compressed, with finely-serrated edges. The fore-limbs are ex-

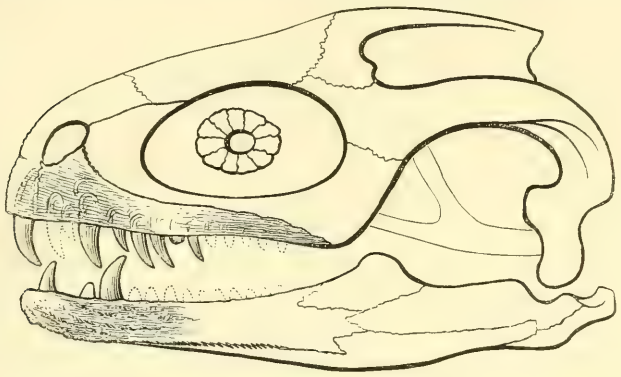

Fig. 578.—Cranium of *Megalosaurus*, restored. (After Professor Phillips.)

traordinarily smaller than the hind-limbs. The teeth do not become worn by mastication; and there appears to have been no exoskeleton. In the Cretaceous deposits of North America the place of *Megalosaurus* is taken by the closely-allied *Lælaps* (or *Dryptosaurus*).

One of the most remarkable of the *Deinosauria* is the little *Compsognathus longipes* of the Lithographic Slate of Solenhofen, regarded by Professor Huxley as the type of a special group (*Compsognatha*) of his order *Ornithoscelida*. The special characters distinguishing this group are, that the cervical region of the spine is long, and the femur is shorter than the tibia; whereas in the typical *Deinosauria* the neck is relatively short, and the femur is as long as, or longer than, the tibia. *Compsognathus* is not remarkable for its size, which does not seem to have been much more than two feet, but for the striking affinities which it exhibits to the true Birds. The head of *Compsognathus* was furnished with *toothed* jaws, and supported upon a long and slender neck. The fore-

limbs were very short, but the hind-limbs were long and like those of Birds. The *proximal* portion of the tarsus resembled that of Birds in being anchylosed to the lower end of the tibia; but the *distal* portion of the tarsus—unlike that of Birds—was free, and was not anchylosed with the metatarsus. Huxley concludes that "it is impossible to look at the conformation of this strange Reptile, and to doubt that it hopped or walked in an erect or semi-erect position, after the manner of a bird, to which its long neck, slight head, and small anterior limbs must have given it an extraordinary resemblance."

The last type of the *Deinosauria* which we shall notice here is the singular genus *Chondrosteosaurus* (= *Camarosaurus*), comprising gigantic reptiles from the Cretaceous formations of Britain and North America. The size reached by some of the species of this genus was enormous, the length probably being sixty or seventy feet, while the massive construction of the skeleton is as remarkable as its mere linear extension. Thus, in an American species, the first cervical vertebra is "twenty inches in length and twelve in transverse diameter, and one of the dorsals measures three and a half feet in the spread of its diapophyses, two and a half feet in elevation, with the centrum thirteen inches in diameter" (Cope). The femur was six feet in length, and the scapula five and a half feet; while the neck was probably ten feet long. The vertebræ (fig. 579) are opisthocœlous, and the centra are hollowed out into large lateral sinuses on each side, which are believed by Owen to have been filled with unossified cartilage, but which Cope looks upon as possibly having contained air. The trunk-ribs are connected with the vertebræ by double articulation, as in the Crocodiles. The neural arches of the vertebræ are immensely elevated (fig. 579), and the sides of the centra are excavated by depressions, which are conjectured by Owen to have lodged saccular processes of the lung, and which Cope believes to have communicated by open foramina with the internal sinuses of the vertebral body. From the immense size of the scapula and humerus, and the proportionately small size of the pelvis, it may be safely inferred that these

enormous reptiles walked upon all-fours; and it seems not unlikely that their habit of existence was really a semi-

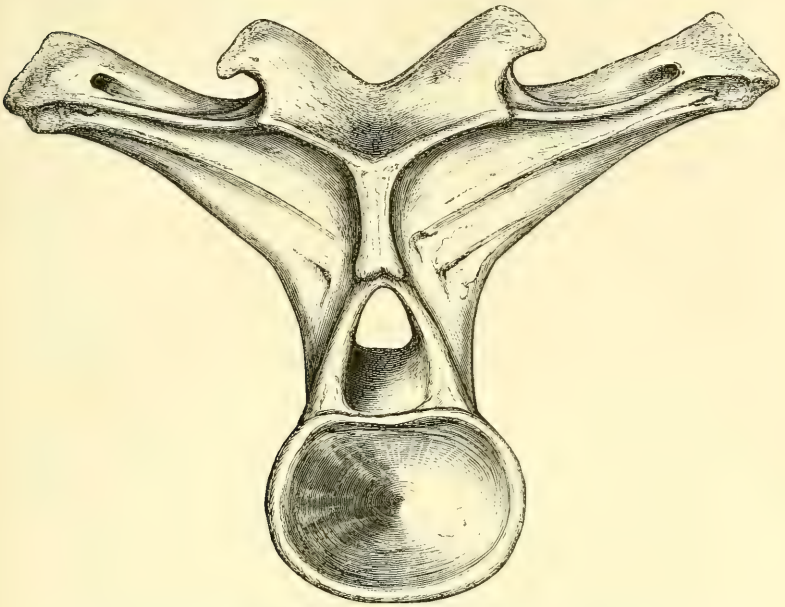

Fig. 579 —Anterior dorsal vertebra of *Chondrosteosaurus* (*Camarosaurus*) *supremus*, reduced in size and viewed from behind. (After Cope.) Cretaceous, North America.

aquatic one. The *Amphicœlias* of the Cretaceous of North America is nearly allied to *Chondrosteosaurus*, and the *Dystrophœus* of the Trias of Utah seems to have belonged to the same group.

It would seem that the genera just mentioned belong to the same natural group of the Deinosaurs as those which Marsh has recently raised to the rank of a sub-order under the name of *Sauropoda*. The genera in question (*Atlantosaurus*, *Morosaurus*, &c.) are from the Jurassic rocks of America, and are characterised by the nearly equal size of the fore and hind limbs, the feet being pentadactylous and plantigrade, and the limb-bones without medullary cavities. The carpal and tarsal bones are distinct; the pubes unite in front by a ventral symphysis; the præcaudal vertebræ contain large cavities, possibly pneumatic; and the neural arches are united to the centra by suture.

Finally, it may just be mentioned that the remains of Deinosaurs (*e.g.*, *Agathaumas*) are found in the so-called "Lignitic Series" of North America, which some high authorities regard as being really of early Tertiary age. The evidence available at present is, however, decidedly in favour of the view that these deposits truly belong to the closing portion of the Cretaceous period.

Order X. Theriodontia.—This order has been founded by Professor Owen for the reception of a number of carnivorous Reptiles from deposits of Triassic or Permian age. The Reptiles in question show some singular Mammalian affinities, especially to the Beasts of Prey. *The dentition is of the carnivorous type, the teeth being in three distinct sets—viz., incisors, canines, and molars, and the canines being large and pointed.*

In *Cynodraco*, which may be regarded as the best known form of the group, the canines are not only of immense size,

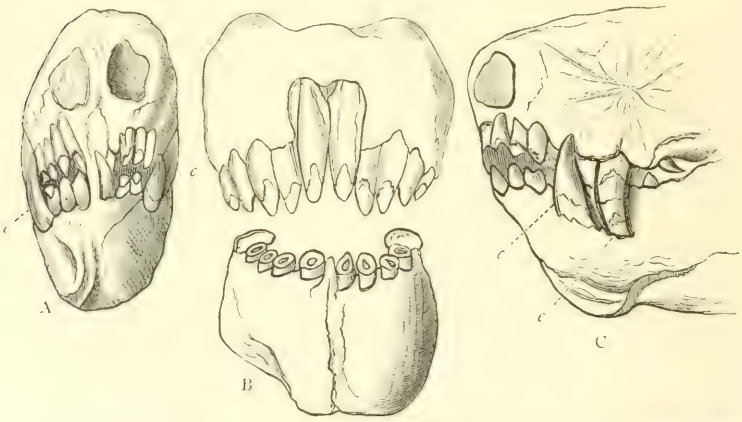

Fig. 580.—A, Front view of the skull of *Lycosaurus*, showing the dentition; B, Front view of the jaws of *Cynodraco scrridens*, showing the incisor teeth; C, Side view of the jaws of *Lycosaurus*, showing the incisors and the laniariform canines. *c*, Canines. (After Owen.)

but are compressed in shape, and have the hinder trenchant border of the tooth minutely serrated, thus somewhat resembling the canines of the Sabre-toothed Tiger (*Machairodus*). The humerus is, further, furnished with a "supra-condyloid foramen" (similar to that of the humerus of the *Felidæ*)

for the protection of the median nerve and brachial artery on their way down the arm. The genus *Cynodraco* (fig. 580, B) is only known as occurring in deposits believed to be of the age of the Trias in South Africa; and the same formation contains a large number of other Reptilian types which are referred by Prof. Owen to the order of the *Theriodontia*. The most important of these are *Lycosaurus* (fig. 580, A and C), *Cynochampsa*, *Galesaurus*, *Tigrisuchus*, and *Cynosuchus*. The eminent palæontologist just mentioned has further indicated that certain Permian Reptiles (*Brithopus*, *Deuterosaurus*, &c.) are probably really referable to the Theriodonts; and it would seem probable that the *Clepsydrops* of Cope, from the Permian rocks of North America, should be regarded as a member of this order.

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CHAPTER XXXVI.

BIRDS.

The fourth class of the *Vertebrata* is that of *Aves*, or Birds. The Birds may be shortly defined as being "oviparous Vertebrates with warm blood, a double circulation, and a covering of feathers" (Owen). More minutely, however, the Birds are defined by the possession of the following characters:—

The skull articulates with the vertebral column by a single occipital condyle. The form of the vertebral centra varies; but they are in no case amphicœlous, except in the extinct Ichthyornis. Each half or ramus of the lower jaw consists of a number of pieces, which are separate from one another in the embryo; and the jaw is united with the skull, not directly, but by the intervention of a quadrate bone (as in the Reptiles). The fore-limb in no existing birds possesses more than three fingers or digits, and the metacarpal bones are anchylosed together. In all living Birds the fore-limbs are useless as regards prehension, and in most they are organs of flight. The hind-limbs in all Birds have the ankle-joint placed in the middle of the tarsus, the proximal portion of the tarsus coalescing with the tibia, and the distal portion of the tarsus being anchylosed with the metatarsus to constitute a single bone known as the "tarso-metatarsus."

The heart consists of four chambers, two auricles and two ventricles; and not only are the right and left sides of the heart completely separated from one another, but there is no

communication between the pulmonary and systemic circulations, as there is in Reptiles.

The respiratory organs are in the form of spongy cellular lungs, which are not freely suspended in pleural sacs; and the bronchi open on their surface into a number of air-sacs, placed in different parts of the body.

All birds are oviparous, none bringing forth their young alive, or being even ovo-viviparous. All birds are, lastly, provided with an epidermic covering, so modified as to constitute what are known as feathers.

The entire *skeleton* of the Birds is singularly compact, and at the same time singularly light. The compactness is due to the presence of an unusual amount of phosphate of lime; and the lightness, to the absence in many of the bones of the ordinary marrow, and its replacement by air.

As regards the *vertebral column*, Birds exhibit some very interesting peculiarities. The cervical region of the spine is unusually long and flexible, since the fore-limbs are useless as organs of prehension—and all acts of grasping must be exercised either by the beak or by the hind-feet, or by both acting in conjunction. The number of vertebræ in the neck varies from eight to twenty-three. The front faces of their centra are cylindroidal (spheroidal in Penguins), *convex from above downwards, and concave from side to side*, the posterior faces being concave from above downwards and convex from side to side. Hence in *vertical* section, the vertebræ appear to be *opisthocœlous*, and in *horizontal* section *procœlous*. This structure of the cervical vertebræ is highly characteristic of Birds. The dorsal vertebræ vary from six to ten in number, and of these the anterior four or five are generally anchylosed with one another, so as to give a base of resistance to the wings. In the Cursorial Birds, however (such as the Ostrich and Emeu), and in some others (such as the Penguin), in which the power of flight is wanting, the dorsal vertebræ are all more or less freely movable one upon another. There are no lumbar vertebræ, but all the vertebræ between the last dorsal and the first caudal (varying from nine to twenty) are anchylosed together to form a bone which is ordinarily known as the "sacrum." To this, in

turn, the iliac bones are anchylosed along their whole length, giving perfect immobility to this region of the spine and to the pelvis.

The coccygeal or caudal vertebræ vary in number from eight to ten, and are movable upon one another. In reality, however, the number of caudal vertebræ is much greater than the above, since some of the vertebræ of the anchylosed "sacrum" properly fall to be counted in this region, and the "ploughshare-bone" consists of more than one vertebra. The most noticeable feature about this part of the spinal column is what is known as the "ploughshare-bone." This is the last joint of the tail, and is a long, slender, ploughshare-shaped bone, destitute of lateral processes, and without any medullary canal (fig. 584, B). In reality it consists of two or more of the caudal vertebræ, completely anchylosed, and fused into a single mass. It is usually set on to the extremity of the spine at an angle more or less nearly perpendicular to the axis of the body; and it affords a firm basis for the support of the great quill-feathers of the tail ("rectrices"). In the Cursorial Birds, which do not fly, the terminal joint of the tail is not ploughshare-shaped. In the extraordinary Mesozoic bird, the *Archæopteryx macrura*, there is no ploughshare-bone, and the tail consists of twenty separate vertebræ, all distinct from one another, and each carrying a pair of quill-feathers, one on each side. As the vertebræ of the ploughshare-bone are distinct from one another in the embryos of existing birds, the tail of the *Archæopteryx* is to be regarded as a case of the permanent retention in the adult of an embryonic character. In the increased number of caudal vertebræ, however, and in some other characters, the tail of the *Archæopteryx* makes a decided approach to that of the true Reptiles.

The various bones which compose the *skull* of Birds are amalgamated in the adult so as to form a single piece, and the sutures even are obliterated, the lower jaw alone remaining movable. The occipital bone carries a single occipital condyle only, and this is hemispherical or nearly globular in shape. The "beak" (fig. 581), which forms such a conspicuous feature in all birds, consists of an upper and lower half,

or a "superior" and "inferior mandible." The upper mandible is composed almost entirely of the greatly-elongated intermaxillary bones, flanked by the comparatively small superior maxillæ. The inferior mandible is primitively com-

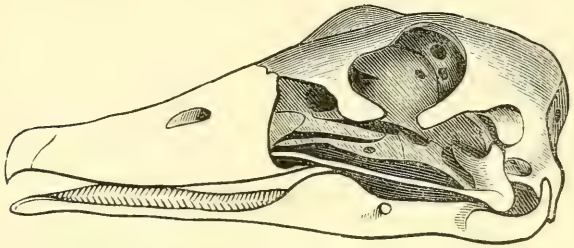

Fig. 581.—Skull of Spur-winged Goose (*Plectropterus Gambensis*).

posed of twelve pieces, six on each side; but in the adult these are all indistinguishably amalgamated with one another, and the lower jaw forms a single piece. As in the Reptiles, the lower jaw articulates with the skull, not directly, but through the intervention of a distinct bone—the quadrate bone or tympanic bone—which always remains permanently movable, and is never anchylosed with the skull. In no living bird are teeth ever developed in either jaw, but both mandibles are encased in horn, forming the beak, and the margins of the bill are sometimes serrated. In the Tertiary *Odontopteryx*, however, the alveolar margins of the jaws are prolonged into tooth-like processes sheathed in the horny substance of the bill; and in the Cretaceous *Odontornithes* true teeth are present.

The thoracic cavity is bounded behind by the dorsal vertebræ, which are usually, as before said, anchylosed with one another to a greater or less extent. Laterally, the thorax is bounded by the ribs, which vary in number from six to ten pairs. In most birds each rib carries a peculiar process —the "uncinate process"—which arises from its posterior margin, is directed upwards and backwards, and passes over the rib next in succession behind, where it is bound down by ligament. The first and last dorsal ribs carry no uncinate processes, and in some cases the processes continue through-

out life as separate pieces (fig. 582, B). Anteriorly, the ribs articulate with a series of straight bones, which are called the "sternal ribs," but which in reality are to be looked upon as the ossified "costal cartilages." These sternal ribs (fig. 582, B) are in turn movably articulated to the sternum

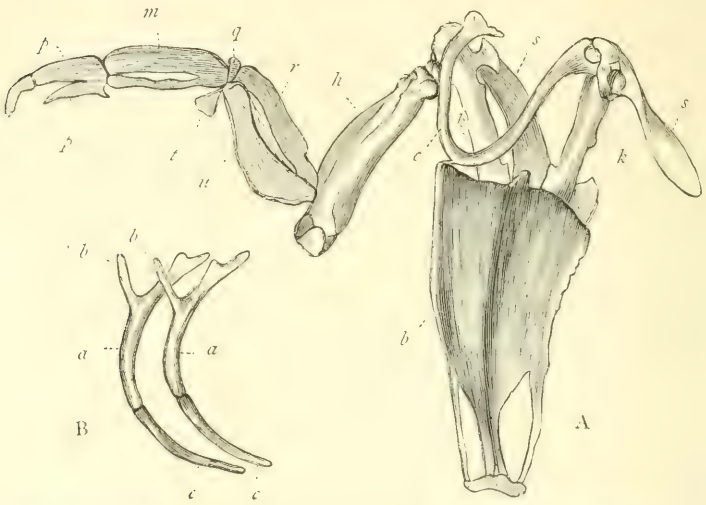

Fig. 582.—A, Breast-bone, shoulder-girdle, and fore-limb of Penguin (after Owen): *b*, Sternum, with the sternal keel; *s*, *s*, Scapulæ; *k*, *k*, Coracoid bones; *c*, Furculum or merry-thought, composed of the united clavicles; *h*, Humerus; *u*, Ulna; *r*, Radius; *t*, Thumb; *m*, Metacarpus; *p*, Phalanges of the fingers. B, Ribs of the Golden Eagle: *a*, *a*, Ribs giving off (*b*, *b*) uncinate processes; *c*, *c*, Sternal ribs.

in front, and "they are the centres upon which the respiratory movements hinge" (Owen). In front the thoracic cavity is completed by an enormously-expanded sternum or breast-bone, which in some birds of great powers of flight extends over the abdominal cavity as well, in some cases even reaching the pelvis. The sternum of all birds which fly, is characterised by the presence of a greatly-developed median ridge or keel (fig. 582, A), to which are attached the great pectoral muscles which move the wings. As a general rule, the size of this sternal crest allows a very tolerable estimate to be formed of the flying powers of the bird to which it may have belonged; and in the Ostriches and other birds which do not fly, there is no sternal keel (fig. 583).

At its anterior angles the sternum exhibits two pits for the attachment of the coracoid bones.

The scapular or pectoral arch consists of the shoulder-blade or scapula, the collar-bone or clavicle, and the coracoid bone, on each side. The scapula, as a rule (fig. 582, A, *s*, *s*) is a simple elongated bone, not flattened out into a broad plate, and carrying no transverse ridge, or spinous process. Only a portion of the glenoid cavity for the articulation with the head of the humerus is formed by the scapula, the remainder being formed by the coracoid. The coracoid bones (fig. 582, A, *k*, *k*) correspond with the coracoid processes of man, but in birds they are distinct bones, and are not anchylosed with the scapula. The coracoid bone on each side is always the strongest of the bones forming the scapular arch. Superiorly it articulates with the clavicle and scapula, and forms part of the glenoid cavity for the humerus. Inferiorly each coracoid bone articulates with the upper angle of the sternum. The position of the coracoids is more or less nearly vertical, so that they form fixed points for the action of the wings in their downward stroke. The clavicles (fig. 582, A, *c*) are rarely rudimentary or absent, and are in some few cases separate bones. In the great majority, however, of birds, the clavicles are anchylosed together at their anterior extremities, so as to form a single bone, somewhat V-shaped, popularly known as the "merry-thought," and technically called the "furculum." The outer extremities of the furculum articulate with the scapula and coracoid; and the anchylosed angle is commonly united by ligament to the top of the sternum. The function of the clavicular or furcular arch is "to oppose the forces which tend to press the humeri inwards towards the mesial plane, during the downward stroke of the wing" (Owen). Consequently the clavicles are stronger, and their angle of union is more open, in proportion to the powers of flight possessed by each bird.

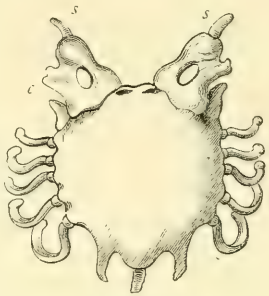

Fig. 583.—Sternum of the Ostrich. *s*, Scapula; *c*, Coracoid.

As regards the structure of the wing proper, the humerus is short and strong, and articulates superiorly with an articular cavity formed partly by the coracoid and partly by the scapula. The fore-arm is composed of a radius and ulna, of which the former is the smallest and most slender. The carpus is reduced to two small bones wedged in between the distal end of the fore-arm and the metacarpus. One other bone of the normal carpus (namely, the "os magnum") is present, but this is anchylosed with one of the metacarpals. There are thus really *three* carpal bones, though only two appear to be present. (According to Morse, there is a *fourth* carpal, which early anchyloses with the base of the metacarpal of the middle finger). The carpus is followed by the metacarpus, the condition of which agrees with that of the carpal bones. The two outermost of the normal five metacarpals are absent, and the remaining three are anchylosed—together with the os magnum—so as to form a single bone (fig. 582, A, *m*). This bone, however, appears externally as if formed of *two* metacarpals united to one another at their extremities, but free in their median portion. The metacarpal bone which corresponds to the radius is always the larger of the two (as being really composed of two metacarpals), and it carries the digit which has the greatest number of phalanges. This digit corresponds with the "index" finger, and it is composed of two, or sometimes three, phalanges. At the proximal end of this metacarpal, at its outer side, there is generally attached a single phalanx, constituting the so-called "thumb," which carries the "bastard-wing," and is sometimes furnished with a claw. The digit which is attached to the ulnar metacarpal corresponds to the middle finger, and never consists of more than a single phalanx.

As regards the structure of the posterior extremity or hind-limb, the pieces which compose the innominate bones (namely, the ilium, ischium, and pubes) are always anchylosed with one another; and the two innominate bones are also always anchylosed, by the medium of the greatly-elongated ilia, with the sacral region of the spine. In no living bird, however, with the single exception of the Ostrich, are the innominate bones united in the middle line in front by a symphysis

pubis. The stability of the pelvic arch, necessary in animals which support the weight of the body on the hind-limbs alone, is amply secured in all ordinary cases by the anchylosis of the ilia with the sacrum.

As in the higher Vertebrates, the lower limb (fig. 584, A) consists of a femur, a tibia and fibula, a tarsus, metatarsus, and phalanges; but some of these parts are considerably obscured by anchylosis. The femur or thigh-bone (fig. 584, A, *f*) is generally very short, comparatively speaking. The chief bone of the leg is the tibia (*t*), to which a thin and

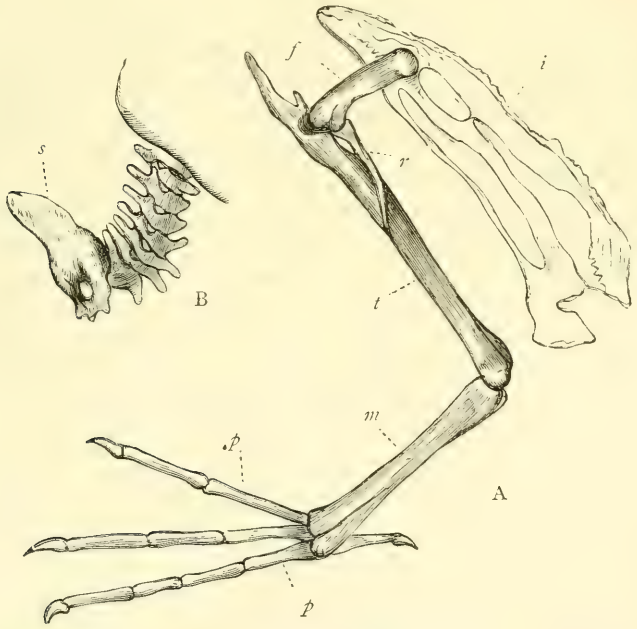

Fig. 584.—A, Hind-limb of the Loon (*Colymbus glacialis*)—after Owen: *i*, Innominate bone; *f*, Thigh-bone or femur; *t*, Tibia, with the proximal portion of the tarsus anchylosed to its lower end; *r*, Fibula; *m*, Tarso-metatarsus, consisting of the distal portion of the tarsus anchylosed with the metatarsus; *p*, *p*, Phalanges of the toes. B, Tail of the Golden Eagle: *s*, Ploughshare-bone, carrying the great tail-feathers.

tapering fibula (*r*) is anchylosed. The upper end of the fibula, however, articulates with the external condyle of the femur. The ankle-joint is placed, as in Reptiles, between the proximal and distal portions of the tarsus. The proximal

portion of the tarsus, consisting of two bones representing the astragalus and calcaneum or the former only, is undistinguishably amalgamated with the lower end of the tibia. The distal portion of the tarsus is anchylosed with the second, third, and fourth metatarsals to constitute the most characteristic bone in the leg of the Bird—the "tarso-metatarsus" (*m*). In most of the long-legged birds, such as the Waders, the disproportionate length of the leg is given by an extraordinary elongation of the tarso-metatarsus.

The tarso-metatarsus is followed inferiorly by the digits of the foot. In most birds the foot consists of three toes directed forwards and one backwards—four toes in all. In no wild bird are there *more* than four toes, but often there are only three, and in the Ostrich the number is reduced to two. In all birds which have three anterior and one posterior toe, it is the posterior thumb or *hallux* (that is to say, the innermost digit of the hind-limb) which is directed backwards; and it invariably consists of two phalanges only, its metatarsal being incomplete and united, as a rule, to the tarso-metatarsus by ligament only. The most internal of the three anterior toes (the "index") consists of three phalanges; the next ("middle") has four phalanges; and the outermost toe ("annularis") is made up of five phalanges (fig. 584, A). This increase in an arithmetical ratio of the phalanges of the toes, in proceeding from the inner to the outer side of the foot, obtains in almost all birds, and enables us readily to detect which digit is suppressed, when the normal four are not all present. Variations of different kinds exist, however, in the number and disposition of the toes. In many birds —such as the Parrots—the outermost toe is turned backwards, so that there are two toes in front and two behind; whilst in the Trogons the inner toe is turned back with the hallux, and the outermost toe is turned forwards. In others, again, the outer toe is normally directed forwards, but can be turned backwards at the will of the animal. In the Swifts, on the other hand, all four toes are present, but they are all turned forwards. In many cases—especially amongst the Natatorial birds—the hallux is wholly wanting, or is rudimentary. In the Emeu, Cassowary, Bustards, and other

genera, the hallux is invariably absent, and the foot is three-toed. In the Ostrich both the hallux and the next toe ("index") are wanting, and the foot consists simply of two toes, these being the third and fourth digits.

As regards the *geological distribution* of Birds, there are many reasons why we should be cautious in reasoning upon merely negative evidence, and more than ordinarily careful not to infer the non-existence of birds during any particular geological epoch, simply because we can find no positive evidence for their presence. As Sir Charles Lyell has well remarked, "the powers of flight possessed by most birds would insure them against perishing by numerous casualties to which quadrupeds are exposed during floods;" and, "if they chance to be drowned, or to die when swimming on water, it will scarcely ever happen that they will be submerged so as to become preserved in sedimentary deposits," since, from the lightness of the bones, the carcass would remain long afloat, and would be liable to be devoured by predaceous animals. As, with a few utterly trivial exceptions, all the deposits in which fossils are found have been laid down in water, and more especially as they are for the most part marine, these considerations put forward by Sir Charles Lyell afford obvious ground against the anticipation that the remains of birds should be either of frequent occurrence or of a perfect character in any of the fossiliferous rocks. In accordance with these considerations, as a matter of fact, most of the known remains of birds are either fragmentary, or belong to forms which were organised to live a terrestrial life, and were not adapted for flight.

The earliest remains which have been generally referred to birds are in the form of footprints (fig. 585) impressed upon certain sandstones in the valley of the Connecticut river in the United States. These sandstones are almost certainly Triassic; and if the ornithic character of these footprints be admitted, then Birds date their existence from the commencement of the Mesozoic period, and, for anything we know to the contrary, may have existed during the Palæozoic epoch.

The evidence as to the ornithic character of the footprints in the American Trias is as follows :—

Firstly, The tracks appear to be certainly those of a *biped* —that is to say, of an animal which often, if not always,

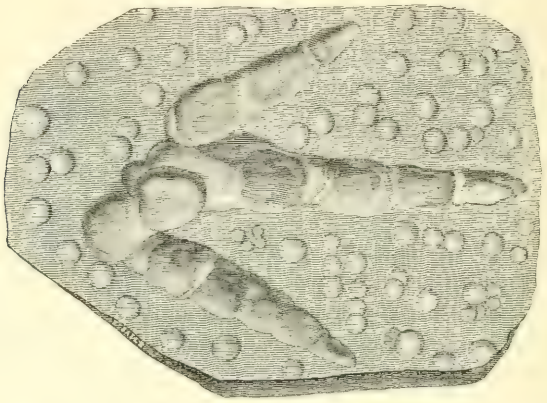

Fig. 585.—Footprint supposed to belong to a Bird. Triassic Sandstones of Connecticut.

walked upon two legs. No living animals walk habitually upon two legs except Man and Birds, and therefore there is a *primâ facie* presumption that the authors of these prints were birds.

Secondly, The impressions are mostly tridactylous—that is to say, formed by an animal with three toes on each foot, as is the case in many Waders and most Cursorial Birds.

Thirdly, The impressions of the toes show the same numerical progression in the number of phalanges as exists in living birds—that is to say, the innermost of the anterior toes has three phalanges, the middle one has four, and the outermost toe has five phalanges.

Taking this evidence collectively, it would have seemed, till lately, tolerably certain that these impressions were formed by Birds. In spite, however, of the general resemblance of these footprints to those of Birds, the balance of evidence at the present moment is in favour of the view that they are, in great part, and perhaps wholly, the work of *Reptiles*. Some of the three-toed footprints have been shown to be accompanied with the recognisable traces of the

impressions of a much smaller anterior pair of feet. Others of the impressions are four-toed, and must certainly have been formed by Reptiles; while the bones of Deinosaurs have actually been found in the same beds. Putting these facts together with the strong probability that the Deinosaurs in some cases temporarily or permanently adopted a bipedal mode of progression, it seems tolerably certain that most of the footprints of the Connecticut Trias were produced by Reptiles, though there still remains the possibility that some are ornithic.

The size and other characters of the above-mentioned impressions vary much, and they have certainly been produced by several different animals. In the largest hitherto discovered, each footprint is twenty-two inches long, and twelve inches wide, showing that the feet were four times as large as those of the African Ostrich. The animal, therefore, which produced these impressions—whether Avian or Reptilian—must have been of gigantic size.

The first unmistakable remains of a bird have been found in the Solenhofen Slates of Bavaria, of the age of the Upper Oolites. A single unique specimen, consisting of bones and feathers, but unfortunately without the skull, is all that has hitherto been discovered; and it has been named the *Archæopteryx macrura*. A second specimen found quite recently has not yet been described. The characters of this singular and aberrant bird, which alone constitutes the order *Saururæ*, will be shortly given, and need not be repeated here.

In the Cretaceous rocks, not only do we find the remains of Birds of the type now existing, but we meet with the extraordinary "Toothed Birds" (*Odontornithes*), which seem not to have survived this period, and which will be spoken of in greater detail later on. Lastly, almost all the existing orders of Birds are represented by the time we reach the middle of the Tertiary period, and the distribution and characters of the more important fossil forms will be treated of in discussing the several orders in question.

CHAPTER XXXVII.

Orders of Birds.

The class *Aves* may be divided into the following four sub-classes :—

I. Ratitæ.—Sternum raft-like, without a prominent keel for the attachment of the great pectoral muscles. The barbs of the feathers not united by the barbules. This sub-class comprises the single order of the *Cursores* or Running Birds, such as the Ostrich, Emeu, Cassowary, &c., all of which are destitute of the power of flight.

II. Carinatæ.—The sternum furnished with a prominent median ridge or keel, to which the muscles of flight are attached. In this sub-class are comprised the existing orders of the *Natatores, Grallatores, Rasores, Scansores, Insessores,* and *Raptores,* in all of which the power of flight is normally more or less developed.

III. Saurornithes.—The caudal vertebræ numerous ; the tail longer than the body, and not terminated by a plough-share-bone. The metacarpals not anchylosed. This sub-class includes only the single order *Saururæ,* comprising only the single Jurassic bird, the *Archæopteryx macrura.*

IV. Odontornithes.—Jaws furnished with true teeth, sunk in distinct sockets or in a continuous groove. Wings well developed or rudimentary. This sub-class comprises the two extinct orders of the *Odontotormæ* and *Odontolcæ,* both of which are confined to the Cretaceous period.

In the following are given the characters of the orders of

the Birds, with the principal fossil forms and geological range of each, so far as known:—

Sub-class I.—Ratitæ.

Order Cursores.—The first order of Birds is that of the *Cursores*, or Runners, comprising the Ostriches, Rheas, Cassowaries, Emeus, and the singular *Apteryx* of New Zealand. The *Cursores* are characterised by *the rudimentary condition of the wings, which are so short as to be useless for flight, and by the compensating length and strength of the legs.* In accordance with this condition of the limbs, many of the bones retain their marrow, and *the sternum* (fig. 583) *is destitute of the prominent ridge or keel, to which the great pectoral muscles are attached* (hence the name of *Ratitæ*, applied by Huxley to the order). In the Ostrich, the pubic bones of the pelvis unite to form a symphysis pubis, as they do in no other bird; and in all, the pelvic arch possesses unusual strength and stability. *The legs are extremely robust and powerful, and the hind-toe is entirely wanting, except in the Apteryx, in which it is rudimentary.* The anterior toes are two or three in number, and are provided with strong blunt claws or nails. *The plumage presents the remarkable peculiarity that the barbs of the feathers, instead of being connected to one another by hooked barbules, as is usually the case, are remote and disconnected from one another, presenting some resemblance to hairs.*

The order *Cursores* may be divided into the two families of the *Struthionidæ* and the *Apterygidæ*—the former characterised by the absence of the hallux, and comprising the Ostrich, Rhea, Emeu, and Cassowary, with several extinct forms; the latter comprising only the *Apteryx* (fig. 586) of New Zealand, and characterised by the possession of a rudimentary hallux.

As regards the distribution of the *Cursores* in *space*, the living forms are restricted to regions which lie, wholly or in great part, to the south of the equator. Thus, the true Ostriches (*Struthio*) are African; the Rheas are South American; the Emeus are Australian; the Cassowaries

are confined to Northern Australia, Papua, and the Indian Archipelago; and the species of *Apteryx* are natives of New Zealand.

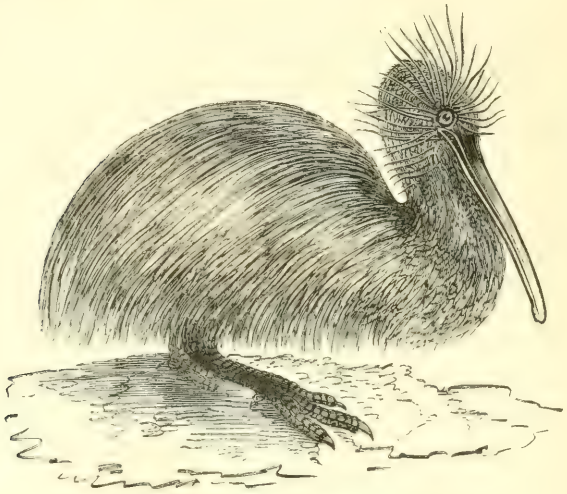

Fig. 586.—*Apteryx Australis.* (Gould.)

As regards the distribution of the *Cursores* in *time*, it would seem probable that some of the footprints of the American Trias (if ornithic at all) were produced by birds belonging to this group. In the present uncertainty as to the nature of these impressions, the first undoubted appearance of Cursorial Birds is in the Eocene Tertiary. In beds of this age in Britain (the London Clay), we have the remains of *Dasornis Londinensis*, a large Struthious bird, with affinities to *Dinornis;* and in strata of Eocene age in New Mexico, Prof. Cope records the discovery of *Diatryma gigantea*, a wingless bird twice the size of the living Ostrich. *Gastornis*, also Eocene, and sometimes placed in the *Cursores*, appears to be truly referable to the *Natatores*.

In the Miocene and Pliocene Tertiary we have no remains of *Cursores* to notice; but in the Post-Pliocene period we meet with a number of extinct forms of the order, all of which, so far, have been found in geographical provinces at present tenanted by great wingless birds. The most in-

teresting of the forms in question occur in the Post-Tertiary and Recent deposits of New Zealand. In this island have been found the remains of a number of large wingless birds, which form the family of the *Dinornithidæ*, of which *Dinornis* (fig. 587) itself is the most important genus. All the

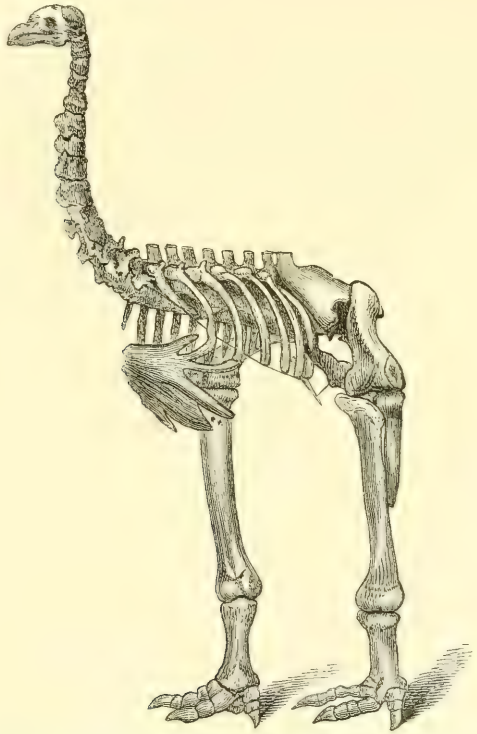

Fig. 587.—Skeleton of *Dinornis elephantopus*, greatly reduced. Post-Pliocene. New Zealand. (After Owen.)

members of this group (*Dinornis, Palapteryx*, &c.) are large Cursorial birds, the wings being useless for flight, and furnished with a rudimentary humerus. The hallux is wanting (*Dinornis*) or present (*Palapteryx*). The largest species is the *Dinornis giganteus*, one of the most gigantic of living or fossil birds, the tibia measuring a yard in length, and the total height being at least ten feet. Another species, the *Dinornis elephantopus* (fig. 587), though not standing more

than about six feet in height, was of an even more ponderous construction—"the framework of the skeleton being the most massive of any in the whole class of Birds," whilst "the toe-bones almost rival those of the Elephant" (Owen). The feet in *Dinornis* were furnished with three toes, and are of interest as presenting us with an undoubted Bird big enough to produce the largest of the footprints of the Triassic Sandstones of Connecticut. New Zealand has now been so far explored, that it seems questionable if it can retain in its recesses any living example of *Dinornis;* but it is certain that species of this genus were alive during the human period, and survived up to quite a recent date. Not only are the bones very numerous in certain localities, but they are found in the most recent and superficial deposits, and they still contain a considerable proportion of animal matter; whilst in some instances bones have been found with the feathers attached, or with the horny skin of the legs still adhering to them. Charred bones have been found in connection with native "ovens;" and the traditions of the Maories contain circumstantial accounts of gigantic wingless Birds, the "Moas," which were hunted both for their flesh and their plumage.

In Madagascar, bones have been discovered of another huge wingless Post-Tertiary Bird, which must have been as large as, or larger than, the *Dinornis giganteus,* and which has been described under the name of *Æpiornis maximus.* With the bones have been found eggs measuring from thirteen to fourteen inches in diameter, and computed to have the capacity of three ostrich-eggs. At least two other smaller species of *Æpiornis* have been described by Grandidier and Milne-Edwards as occurring in Madagascar; and they consider the genus to be so closely allied to the *Dinornis* of New Zealand, as to prove that these regions, now so remote, were at one time united by land. Another point which would favour this view is the existence in the Post-Tertiary of the Mascarene Islands of a wingless bird (the *Erythromachus Leguati*), which A. Milne-Edwards considers to be allied to the living *Apteryx* of New Zealand. The former existence of Cursorial birds in regions now inhabited by

members of the same order is further exemplified by the occurrence of remains of birds belonging to the South American genus *Rhea* in the Post-Tertiary cave-deposits of Brazil.

Lastly, the Post-Tertiary deposits of Australia have yielded the remains of an extinct Struthious bird allied to the Emeu, which has been described under the name of *Dromæornis*.

Sub-class II.—Carinatæ.

Order I. Natatores (*Palmipedes*).—The order of the *Natatores*, or Swimmers, comprises a number of Birds which are as much or even more at home in the water than upon the land. In accordance with their aquatic habit of life, the *Natatores* have *a boat-shaped body, usually with a long neck. The legs are short, and placed behind the centre of gravity of the body, this position enabling them to act admirably as paddles, at the same time that it renders the gait upon dry land more or less awkward and shuffling. In all cases the toes are "webbed" or united by membrane to a greater or less extent.* In many instances the membrane or web is stretched completely from toe to toe, but in others the web is divided or split up between the toes, so that the toes are fringed with membranous borders, but the feet are only imperfectly webbed.

Amongst the more important families of the *Natatores* may be enumerated the Penguins (*Spheniscidæ*), the Auks (*Alcidæ*), the Gulls and Terns (*Laridæ*), the Petrels (*Procellaridæ*), the Pelicans (*Pelicanus*), the Cormorants (*Phalacrocorax*), the Gannets (*Sula*), the Ducks (*Anatidæ*), the Geese (*Anserinæ*), and the Swans (*Cygnidæ*).

As might have been expected, the remains of Natatorial Birds are, speaking comparatively, not uncommon as fossils. The earliest traces of this order in past time appear in the Cretaceous series, which has yielded in Europe the *Cimolornis* (supposed to be allied to the Albatross), and in North America the genera *Laornis* and *Graculavus*, the former related to the Swans, while the latter has affinities with the living *Graculus*. In the Eocene Tertiary we meet with

various interesting types of the *Natatores*. Among these, *Gastornis* is a huge and aberrant example of the *Anserinæ*, with some Grallatorial affinities, and approaching the *Cursores* in the fact that the wings were rudimentary, and the power of flight, therefore, wanting. The only known species is the *Gastornis Parisiensis* of the Paris basin. The *Argillornis* of the Eocene Tertiary appears to have been an ancient representative of the Albatross (*Diomedea exulans*), considerably exceeding the living species in size. *Agnopterus*, again, is an Eocene bird allied to the Flamingo. Under this order also probably comes the extraordinary fossil bird, recently described by Professor Owen from the London Clay (Eocene) of Sheppey under the name of *Odontopteryx toliapicus*. In this singular bird (fig. 588) the alveolar margins of both jaws are furnished with tooth-like denticulations, which differ from true teeth in being actually parts of the osseous substance of the jaw itself, with which they are continuous. They are of triangular or compressed conical form, and are of two sizes, the larger ones resembling canines. From the consideration of all the discovered remains of this bird, Professor Owen concludes that "*Odontopteryx* was a warm-

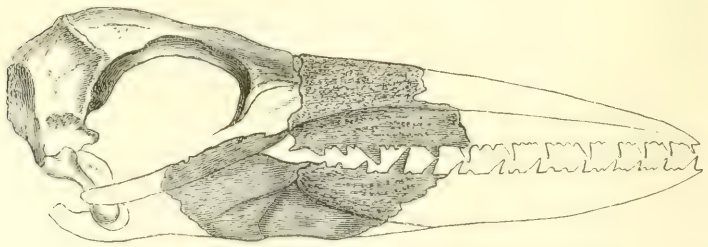

Fig. 588.—Skull of *Odontopteryx toliapicus*, restored. (After Owen.)

blooded feathered biped, with wings; and further, that it was web-footed and a fish-eater, and that in the catching of its slippery prey it was assisted by this Pterosauroid armature of its jaws." Upon the whole, *Odontopteryx* would appear to be most nearly allied to the *Anatidæ*, but the denticulation of its jaws is an entirely unique character.

In the Miocene Tertiary are found the remains of various Natatorial birds, among which may be mentioned Flamingoes,

hardly separable from existing species, together with *Pelagornis*, an extinct ally of the Pelicans.

Of the Pliocene and Post-Tertiary *Natatores*, the only form requiring notice is the great extinct *Cnemiornis* of the Post-Tertiary deposits of New Zealand. The remains of this bird indicate that it was an aberrant member of the *Anserinæ*, most nearly allied to the living *Cereopsis* of Australia, but resembling the *Cursores* in the massive construction of the hind-limbs and the rudimentary condition of the wings.

Order II. Grallatores.—The birds comprised in the order of the *Grallatores*, or Waders, for the most part frequent the banks of rivers and lakes, or the shores of estuaries, marshes, lagoons, and shallow pools, though some of them keep almost exclusively to dry land, preferring, however, moist and damp situations. In accordance with their semi-aquatic amphibious habits, the Waders are distinguished by *the great length of their legs; the increase in length being mainly due to the great elongation of the tarso-metatarsus. The legs are also unfeathered from the lower end of the tibia downwards. The toes are elongated and straight, and are never completely palmate, though sometimes semi-palmate. There are three anterior toes, and usually a short hallux, but the latter may be wanting.* The wings are long, and the power of flight usually considerable; but the tail is short, and the long legs are stretched out behind in flight to compensate for the brevity of the tail. The body is generally slender, and the neck and beak usually of considerable length.

Amongst the more important Grallatorial Birds are the Rails (*Rallidæ*), Water-hens (*Gallinulæ*), Cranes (*Gruidæ*), Herons (*Ardeidæ*), Storks (*Ciconinæ*), Snipes (*Scolopacidæ*), Sandpipers (*Tringidæ*), Curlews (*Numenius*), Plovers (*Charadriidæ*), and Bustards (*Otidæ*).

As in the case of the *Natatores*, the earliest traces of the Waders appear to belong to the Cretaceous period, and are found in deposits of this age in the North American area. The forms in question constitute the genera *Palæotringa* and *Telmatornis*, the former being allied to the Sandpipers, while the latter is rather related to the Rails.

In the Eocene Tertiary various Grallatorial birds have

been detected, one of the most remarkable being a gigantic Rail (*Gypsornis*) from the Paris basin. Deposits of the same age in North America have yielded the wading *Aletornis*. In the Miocene strata of Europe are found Waders allied to the living Godwits and Storks, constituting respectively the genera *Elornis* and *Ibidipodia*. Lastly, in the Post-Tertiary deposits are found some interesting types of *Grallatores*, which require notice, as they have the peculiarity that the wings were rudimentary and useless for flight. One of the most remarkable of these is the *Aphanapteryx* of the Post-Tertiary of the island of Mauritius, a large Ralline bird, which was incapable of flying. It was allied to the living *Ocydromus*, and survived into the human period, having been apparently exterminated at a comparatively late date. Equally peculiar are the *Aptornis* and *Notornis* of New Zealand, both large birds, of Ralline affinities, but unable to fly. The former of these appears to be really extinct; but the latter, long believed to be so, has now been found living, and has been shown to be a gigantic and wingless Coot.

Order III. Rasores.—The third order of Carinate Birds is that of the *Rasores*, or Scratchers, often spoken of collectively as the "Gallinaceous" birds, from the old name of "Gallinæ," given to the order by Linnæus. The *Rasores* are characterised by *the convex, vaulted upper mandible, having the nostrils pierced in a membranous space at its base. The nostrils are covered by a cartilaginous scale.* Taking the *Gallinacei* as the type of the order, the *legs are strong and robust, mostly covered with feathers as far as the joint between the tibia and tarso-metatarsus. There are four toes, three in front and one behind, the latter being short, and placed at a higher level than the other toes. All the toes terminate in strong blunt claws suitable for scratching* (*Gallinacei*), or in more slender claws adapted for perching (*Columbacei*).

The order *Rasores* is divided into two sub-orders, typified respectively by the Fowls and the Pigeons, and termed the *Gallinacei* and *Columbacei*. In the former are included the Grouse and its allies (*Tetraonidæ*); the Partridges and Quails (*Perdicidæ*); the Pheasants, Pea-fowl, Turkey, and Domestic Fowl (*Phasianidæ*); the Sand-grouse (*Pteroclidæ*); the Bush

Quails (*Turnicidæ*); the Mound-birds (*Megapodidæ*); the Curassows (*Cracidæ*); and the Tinamous (*Tinamidæ*). In the latter are comprised the Pigeons (*Columbidæ*), the Ground-Pigeons (*Gouridæ*), the Tree-Pigeons (*Treronidæ*), the *Didunculidæ*, and the curious extinct family of the *Didida*.

As regards their *distribution in time*, the earliest known traces of the *Rasores* are found in the Eocene Tertiary. In beds of this age in France occurs the Gallinaceous genus *Palæortyx*, apparently allied to the existing Quails in some respects, but very different in others.

In the Miocene period occur the remains of both Gallinaceous and Columbaceous birds, one of the most noticeable of the former being a Turkey (*Meleagris antiquus*) from the Miocene of Colorado. The European Miocene contains remains of Pheasants (*Phasianus*), Partridges (*Palæoperdix*), Sand-grouse, and Pigeons. The later Tertiary and Post-Tertiary deposits have also yielded the bones of various Rasorial birds, the genus *Gallus* appearing for the first time in the Pliocene. The most interesting, however, of the extinct *Rasores* are the Dodo and the Solitaire, both of which have been exterminated within the historical period. Of these two singular birds, the Dodo (*Didus inceptus*) formerly inhabited the island of Mauritius in great numbers, but the last record of its occurrence dates from the year 1681. It was a large and heavy bird (fig. 589), bigger than a swan, and entirely unlike the Pigeons in general appearance. The wings were rudimentary and completely useless as organs of flight. The legs were short and stout, the feet had four toes each, and the tail was extremely short, carrying, as well as the wings, a tuft of soft plumes. The beak (unlike that of any of the *Columbacei* except the little *Didunculus strigirostris*) was strongly arched towards the end, and the upper mandible had a strongly-hooked apex, not at all unlike that of a bird of prey. The frontal region of the skull was greatly elevated and tumid, from the excessive development of cellular cavities between the two tables of the skull, and the actual brain-case was very small in proportion to the size of the cranium.

In many respects allied to the Dodo, and, like it, incapable

of flight, is the Solitaire (*Pezophaps*) of Rodriguez, a small island lying about three hundred miles to the east of Mauritius. Its last recorded appearance was in the year 1693. The Solitaire had longer legs and a longer neck than the Dodo; its bill was less strongly arched; its forehead was flatter; and there was developed upon the radial side of the metacarpal an extraordinary spherical callus-like mass

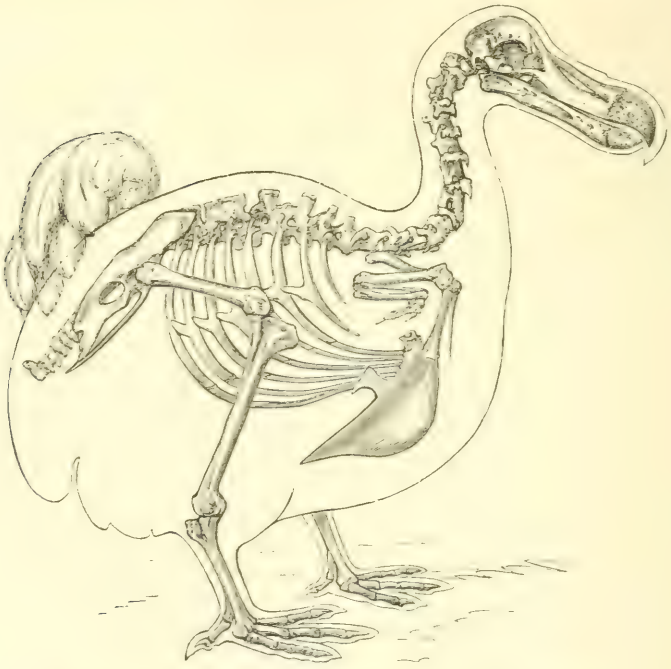

Fig. 589.—Skeleton of the Dodo (*Didus ineptus*), restored. (After Owen.)

of bone, about as large as a musket-ball, and with a roughened surface. This singular callosity is much more developed in certain individuals—supposed to be males—than in others, which we may presume to be females; it was doubtless covered during life by a horny integument; and it seems to have been used as an offensive weapon.

Order IV. Scansores.—The order of the Scansorial or Climbing Birds is easily and very shortly defined, having no

other distinctive and exclusive peculiarity except the fact that *the feet are provided with four toes, of which two are turned backwards and two forwards. Of the two toes which are directed backwards, one is the hallux or proper hind-toe, and the other is the outermost of the normal three anterior toes.* This arrangement of the toes enables the *Scansores* to climb with unusual facility. Their powers of flight, on the other hand, are generally only moderate and below the average.

The most important families of the *Scansores* are the Cuckoos (*Cuculidæ*), the Woodpeckers and Wry-necks (*Picidæ*), the Parrots (*Psittacidæ*), the Toucans (*Rhamphastidæ*), the Trogons (*Trogonidæ*), the Barbets (*Bucconidæ*), and the Plantain-eaters (*Musophagidæ*).

The range of the *Scansores* in *time* does not appear to be extensive, the earliest known representative of the order being from the lower Tertiary. The Eocene beds of Wyoming have yielded the remains of a Woodpecker (*Uintornis*), and Parrots, Trogons, Cuckoos, and Woodpeckers are known to have lived during the later Tertiary and Post-Tertiary periods. The Miocene beds of France have yielded remains of Trogons and Parrots, with forms related to the Plantain-eaters (*Necrornis*), and others either referable to the Woodpeckers (*Picus*) or allied to these (*Homalophus*).

Order V. Insessores.—The fifth order of Carinate Birds is that of the *Insessores*, or Perchers—often spoken of as the *Passeres*, or "Passerine" Birds. They are defined by Owen as follows: "*Legs slender, short, with three toes before and one behind, the two external toes united by a very short membrane.*"

The *Insessores* form the largest order of existing birds, comprising all the ordinary "song-birds," and including a great number of families. The earliest known remains of Insessorial birds appear in the Eocene Tertiary. Thus in the Lower Eocene Slates of Glaris, we have the *Protornis Glarisiensis*, apparently allied to the Larks; the *Halcyornis toliapicus* of the London Clay may be an old representative of the Kingfishers; the Upper Eocene *Cryptornis* seems to be allied to the Hornbills; and the *Laurillardia* and *Palæogithalus* of the same formation are peculiar Passerine types. In the Miocene Tertiary we have Crows (*Corvus*), Wagtails

(*Motacilla*), and Shrikes (*Lanius*), with forms allied to the Edible-nest Swifts (*Collocalia*) and to the Hoopoes (the extinct *Limnatornis*). The *Palæospiza bella* of the Tertiary of Colorado—remarkable for its beautiful state of preservation—appears to be a Finch. Lastly, the Insessorial remains of the late Tertiary and Post-Tertiary deposits present no features of special interest.

Order VI. Raptores (*Aëtomorphæ*).—All the members of this order are characterised by the shape of *the bill, which is "strong, curved, sharp-edged, and sharp-pointed, often armed with a lateral tooth"* (Owen). *The upper mandible is the longest* (fig. 590, B), *and is strongly hooked at the tip. The body is very muscular; the legs are robust, short, with three toes in front and one behind, all armed with long, curved, crooked claws or talons* (fig. 590, A); *the wings are commonly pointed, and of considerable size, and the flight is usually rapid and powerful.*

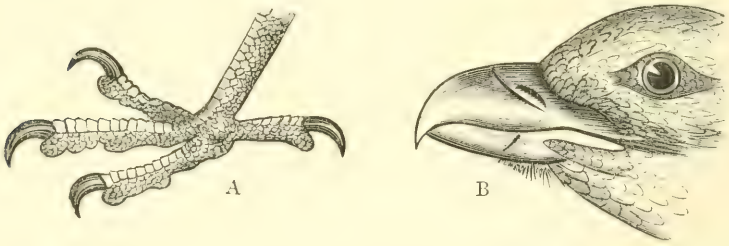

Fig. 590.—A, Foot of the Peregrine Falcon; B, Head of Buzzard.

The order *Raptores* is divided into the two sections of the *Nocturnal* and *Diurnal Raptores*, comprising respectively the forms which fly by night and those which fly by day. In the former are only the Owls, and in the latter are the Hawks, Falcons, Eagles, and Vultures.

As regards the distribution of the *Raptores* in *time*, both the Diurnal and Nocturnal sections of the order seem to have been differentiated in the early Tertiary period; the former being represented by the *Lithornis vulturinus* of the London Clay, a relative of the American Vultures (*Cathartidæ*), while the *Bubo leptosteus* of the Eocene of Wyoming is an example of the latter. In the European Miocene we

meet with Eagles, Kites, Owls, Secretary-birds, and several extinct types (such as *Palæocercus* and *Palæëtus*). Of the Post-Tertiary *Raptores* the most interesting is the *Harpagornis* of New Zealand, a colossal bird of prey which was a contemporary of the Moas.

Sub-class III.—Saurornithes.

Order I. Saururæ.—This order includes only the extinct bird, the *Archæopteryx macrura* (fig. 591), a single specimen of which—and that but a fragmentary one [1]—has been discovered in the Lithographic Slates of Solenhofen (Upper Oolites). This extraordinary bird appears to have been about as big as a Rook; but it differs from all known birds in having two free claws belonging to the wing, and in

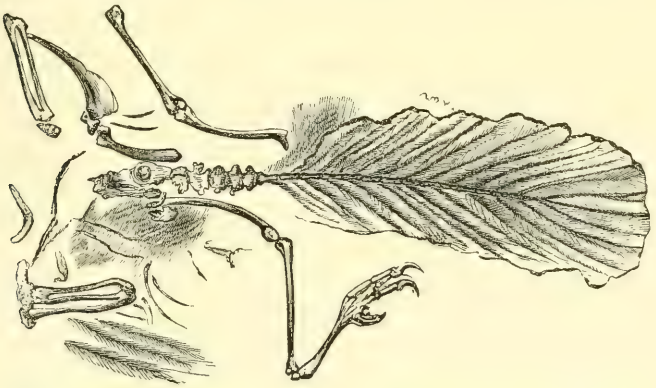

Fig. 591.—*Archæopteryx macrura*, showing tail and tail-feathers, with detached bones.

having *a long lizard-like tail, longer than the body, and composed of separate vertebræ. The tail was destitute of any ploughshare-bone, and each vertebra carried a single pair of quills. The metacarpal bones, also, were not anchylosed together as they are in all other known birds, living or extinct, and two of the digits appear to have been unguiculate.*

[1] A second, and seemingly more perfect, specimen of *Archæopteryx* has recently been discovered in the Solenhofen Slates, but no description of this has as yet been published.

The sub-class *Saurornithes* includes only the single order *Saururæ*, of which no other representative is known than the Jurassic *Archæopteryx*. From the presence of feathers it may be inferred that *Archæopteryx* was hot-blooded, and this character, taken along with the structure of the extremities, is sufficient to justify the reference of this unique fossil to the Birds. In the long lizard-like tail, composed of numerous free vertebræ, each of which bears a pair of tail-feathers, in the fact that the metacarpals were not anchylosed together, and in the possession of two free clawed digits to the manus, *Archæopteryx* differs from all other known birds, living or extinct. There is also some reason to believe that the jaws were furnished with teeth sunk in distinct sockets.

Sub-class IV. Odontornithes.

Order I. Odontolcæ.—This order has been founded by Marsh for the reception of the extraordinary *Hesperornis regalis*, from the Cretaceous rocks of North America. In this wonderful fossil we have a gigantic diving-bird somewhat resembling the true "Divers" or "Loons" (*Colymbus*), but having the jaws furnished with numerous conical recurved *teeth*, sunk in a deep continuous groove (fig. 592, *b* and *d*).

The front of the upper jaw does not carry teeth, and was probably encased in a horny beak. The breast-bone is entirely destitute of a central ridge or keel, and the wings are minute and quite rudimentary; so that *Hesperornis*, unlike *Ichthyornis*, must have been wholly deprived of the power of flight, in this respect approaching the existing Penguins. The tail consists of about twelve vertebræ, of which the last three or four are amalgamated to form a flat terminal mass, there being at the same time clear indications that the tail was capable of up and down movement in a vertical plane, this probably fitting it to serve as a swimming-paddle or rudder. The vertebræ of the cervical and dorsal regions are of the ordinary ornithic type. The legs were powerfully constructed, and the feet were adapted to assist the bird in rapid motion through the water. The known

remains of *Hesperornis regalis* (fig. 593) prove it to have been a swimming and diving bird, of larger dimensions than any of the aquatic members of the class of Birds with which we are acquainted at the present day. It appears to have stood

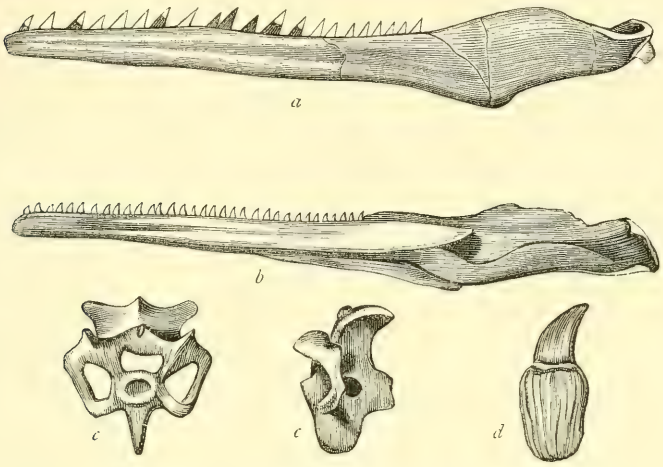

Fig. 592.—Toothed Birds (*Odontornithes*) of the Cretaceous rocks of America. *a*, Left ower jaw of *Ichthyornis dispar*, slightly enlarged; *b*, Left lower jaw of *Hesperornis regalis*, reduced to nearly one-fourth of the natural size; *c*, Cervical vertebra of *Ichthyornis dispar*, front view, twice the natural size; *c'* Side view of the same; *d*, Tooth of *Hesperornis regalis*, enlarged to twice the natural size. (After Marsh.)

between five and six feet high, and its inability to fly is fully compensated for by the numerous adaptations of its structure to a watery life. Its teeth prove it to have been carnivorous in its habits, and it probably lived upon fishes. *Lestornis crassipes* of the American Cretaceous is nearly related to *Hesperornis;* and the *Enaliornis* of the Cretaceous of Britain is supposed by Prof. Seeley to be perhaps allied to the same genus, but its jaws are unknown.

From the next order, the present is readily distinguished by the fact that *the vertebræ resemble those of recent birds, the sternum is without a keel, the wings are rudimentary, and the teeth are implanted in a groove in the jaw and not in separate sockets.*

Order II. Odontotormæ.—This order has been founded by Marsh for the reception of two remarkable birds, which

he has named *Ichthyornis dispar* and *Apatornis celer*, both from the Cretaceous rocks of North America.

In *Ichthyornis dispar*, which may be taken as the type of the order, the teeth (fig. 592, *a*) were sunk in distinct sockets, and were "small, compressed, and pointed, and all

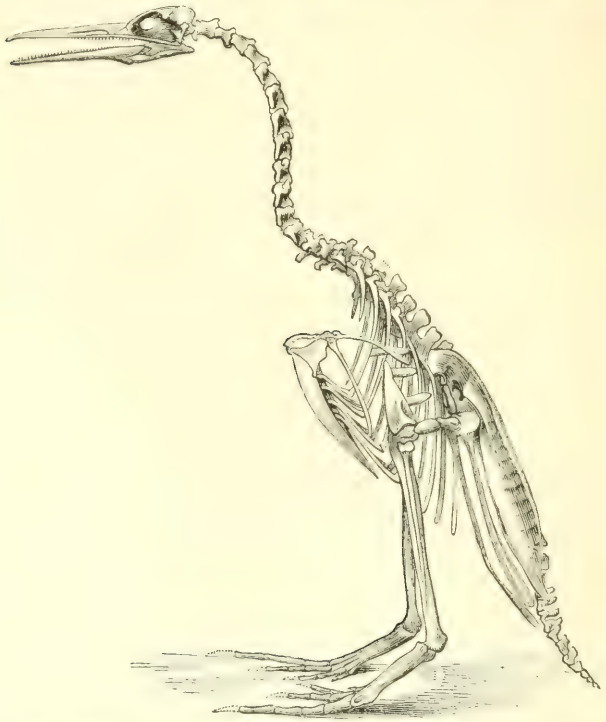

Fig. 593.—Skeleton of *Hesperornis regalis*, restored (after Marsh). About one-tenth of the natural size.

of those preserved are similar. Those in the lower jaw number about twenty in each ramus, and are all more or less inclined backwards. . . . The maxillary teeth appear to have been equally numerous, and essentially the same as those in the mandible. The skull was of moderate size, and the eyes placed well forward. The lower jaws are long and slender, and the rami were not closely united at the symphysis. . . . The jaws were apparently not encased in a horny sheath.

"The scapular arch, and the bones of the wings and legs, all conform closely to the true ornithic type. The wings were large in proportion to the legs, and the humerus had an extended radial crest. The metacarpals were united, as in ordinary birds. The bones of the posterior extremities resemble those of swimming birds. The vertebræ (see fig. 592, *c* and *c'*) were all biconcave, the concavities at each end of the centra being distinct and nearly alike. Whether the tail was elongated cannot at present be determined; but the last vertebra of the sacrum was unusually large.

"The bird was fully adult, and about as large as a pigeon. With the exception of the skull, the bones do not appear to have been pneumatic, though most of them are hollow. The species was carnivorous, and probably aquatic."—(Marsh.)

Apatornis agrees with *Ichthyornis* in most of the above characters, but the structure of its jaws is not fully known. It follows from the above that the order *Odontotormæ* is characterised by the possession of *distinct teeth sunk in separate sockets in the jaw and not in a continuous groove, by the fact that the vertebræ are biconcave, and by the possession of a carinate sternum and well-developed wings.*

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CHAPTER XXXVIII.

MAMMALIA.

General Characters of the Mammalia.

The last and highest class of the *Vertebrata*, that of the *Mammalia*, may be shortly defined as including *Vertebrate animals in which some part or other of the integument is always provided with hairs at some time of life; and the young are nourished for a longer or shorter time, by means of a special fluid—the milk—secreted by special glands—the mammary glands.* These two characters are of themselves sufficient broadly to separate the Mammals from all other classes of the Vertebrate sub-kingdom. In addition, however, to these two leading peculiarities, the Mammals exhibit the following other characters of scarcely less importance:—

1. The skull articulates with the vertebral column by means of a double articulation, the occipital bone carrying two condyles, in place of the single condyle of the Reptiles and Birds.

2. The lower jaw or mandible consists of two halves or rami, united anteriorly by a symphysis, but not necessarily anchylosed; but these are each composed of a single piece, instead of being complex and consisting of several pieces, as in the Reptiles and Birds. Further, the lower jaw always articulates directly with the squamosal element of the skull, and is never united to an os quadratum, as in the *Sauropsida*.

3. The two hemispheres of the cerebral mass, or brain

proper, are united together by a more or less extensively developed "corpus callosum" or commissure.

4. The heart consists—as in Birds—of four cavities or chambers, two auricles and two ventricles. The right and left sides of the heart are completely separated from one another, and there is no communication between the pulmonary and systemic circulations.

5. The cavities of the thorax and abdomen are completely separated from one another by a muscular partition—the diaphragm or midriff.

6. The respiratory organs are in the form of two lungs placed in the thorax, but none of the bronchi end in air-receptacles, distributed through the body, as in Birds.

As regards the *osteology* of the Mammals, the following points should be noticed:—

With the exception of the Whales and Dolphins (*Cetacea*), and the Dugongs and Manatees (*Sirenia*), the vertebral column is divisible into the same regions as in man—namely, into a cervical, dorsal, lumbar, sacral, and caudal or coccygeal region (see fig. 481). In the *Cetacea* and *Sirenia* the dorsal region of the spine is followed by a number of vertebræ which compose the hinder extremity of the body, but which cannot be separated into lumbar, sacral, and caudal vertebræ.

In spite of the great difference which is observable in the length of the neck in different Mammals, the number of vertebræ in the cervical region is extraordinarily constant, being almost invariably seven, as in man. In this respect there is no difference between the Whale and the Giraffe. The only exceptions to this law are the *Manatus australis*, one of the Sea-cows, which has usually six cervical vertebræ; one of the two-toed Sloths, which has only six; and the three-toed Sloth (*Bradypus tridactylus*), which is commonly regarded as possessing nine, though competent anatomists would refer the posterior two of these to the dorsal region.

The dorsal vertebræ are mostly thirteen in number, but they vary from ten to twenty-four. In Man there are twelve, in one of the Armadillos only ten, and in the two-toed Sloth the maximum is attained. The lumbar vertebræ

are usually six or seven in number, rarely fewer than four. In Man they are five in number, and they are reduced to two in the two-toed Sloth, one of the Ant-eaters, and the Duck-mole.

The first vertebra, or atlas, always bears two articular cavities for the reception of the two condyles of the occipital bone, and the second vertebra, or axis, usually has an "odontoid" process on which the head rotates. In the true Whales, however, in which the cervical vertebræ are anchylosed together to a greater or less extent, and the neck is immovable, the odontoid process is also wanting.

The number of lumbar and sacral vertebræ, as we have seen, varies in different Mammals; but ordinarily some of the vertebræ are anchylosed into a single bone, and have the iliac bones abutting against them, thus constituting the "sacrum" of human anatomists. In the *Cetacea* and *Sirenia*, in which the hind-limbs are wanting, and the pelvis rudimentary, there is no "sacrum."

The thoracic cavity or chest in Mammals is always enclosed by a series of ribs, the number of which varies with that of the dorsal vertebræ. In most cases each rib articulates by its head with the bodies of *two* vertebræ, and by its tubercle with the transverse process of one of these vertebræ (the lower one). In the *Monotremata* (*e.g.*, the Duck-mole), the ribs articulate with the body of the vertebra only; and in the Whales, the hindermost of the ribs, or all of them, articulate with the transverse processes only, and not with the centra at all.

There are usually no bony pieces uniting the ribs with the sternum or breast-bone in front, as in Birds; but the so-called "sternal ribs" of *Aves* are represented by the "costal cartilages" of the Mammals. In some cases, however, the cartilages of the ribs do become ossified and constitute sternal ribs. Sometimes, as in the Armadillos, there is a joint between the vertebral rib and costal cartilage. More rarely, as in the *Monotremes*, an intermediate piece is found between the vertebral and costal portions of the rib. Only the anterior ribs reach the sternum, and these are

called the "true" ribs; the posterior ribs, which fall short of the breast-bone, being known as the "false" ribs.

The sternum or breast-bone (fig. 594) is formed of several pieces placed one behind the other, but usually anchylosed together to form a single bone. It is placed upon the ventral surface of the body, and is united with the vertebral

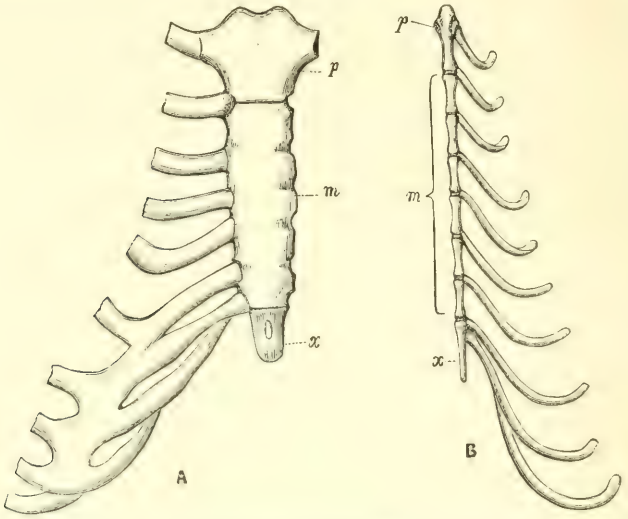


Fig. 594.—A, Sternum of Man, with the costal cartilages. B, Sternum and costal cartilages of the Dog: *p*, Præsternum; *m*, Mesosternum; *x*, Xiphisternum.

column by the ribs and their cartilages. It is generally a long and narrow bone, but in the *Cetacea* it is broad. It is only in some burrowing animals (such as the Moles) and in the true flying Mammals (the Bats), that the sternum is provided with any ridge or keel for the attachment of the pectoral muscles, as it is in Birds. The sternum is primitively composed of three pieces, an anterior piece or *præsternum*, a middle piece or *mesosternum*, and a posterior piece or *xiphisternum*. The præsternum is the "manubrium sterni" of human anatomy, and is the portion of the sternum which lies in front of the attachment of the second pair of ribs. All the other ribs are connected with the mesosternum. The *xiphisternum* is the "xiphoid cartilage" of human anatomy, and it commonly remains throughout life more

or less unossified. In the Monotremes there is a T-shaped bone above or in front of the præsternum, but this is to be regarded as belonging to the shoulder-girdle, and as representing the "episternum" or "interclavicle" of the Reptiles.

The normal number of limbs in the *Mammalia* is four, two anterior and two posterior; and hence they are often spoken of as "quadrupeds," though all the limbs are not universally present, and other animals have four limbs as well. The anterior limbs are not known to be wanting in any Mammal, but the posterior limbs are absent in the *Cetacea* and *Sirenia*.

As regards the structure of the anterior limb, the chief points to be noticed concern the means by which it is connected with the trunk. The scapula or shoulder-blade is never absent, and it is in the form of a broad flat bone, applied to the outer aspect of the ribs, and much more developed than in the Birds. The coracoid bone, which forms such a marked feature in the scapular arch of *Aves*, is fused with the scapula, and only articulates with the sternum in the Duck-mole and Echidna (*Monotremata*). In all other Mammals the coracoid forms merely a process of the scapula, and does not reach the top of the breast-bone. The collar-bones or clavicles never unite in any Mammal to form a "furculum," as in Birds; but in the Monotremes they unite with an "interclavicle" placed in front of the sternum. The clavicles, in point of fact, are not present in a well-developed form in any Mammals except in those which use the anterior limbs in flight, in digging, or in prehension. The *Cetacea*, the Hoofed Quadrupeds (*Ungulata*), and some of the *Edentata*, have no clavicles. Most of the *Carnivora* and some Rodents possess a clavicle, but this is imperfect, and does not articulate with the top of the sternum. The Insectivorous Mammals, many of the Rodents, the Bats, and all the *Quadrumana*, have (with man) a perfect clavicle articulating with the anterior end of the sternum.

The humerus, or long bone of the upper arm (*brachium*), is never wanting, but is extremely short in the Whales, in which the anterior limbs are converted into swimming-paddles.

In the fore-arm of all Mammals the ulna and radius are recognisable, but they are not necessarily distinct; and the radius, as being the bone which mainly supports the hand, is the only one which is always well developed, the ulna being often rudimentary. In the *Cetacea* the ulna and radius are anchylosed together; and in most of the Hoofed Quadrupeds they are anchylosed towards their distal extremities.

The fore-arm is succeeded by the small bones which compose the wrist or "carpus." These are eight in number in man, but vary in different Mammals from five to eleven.

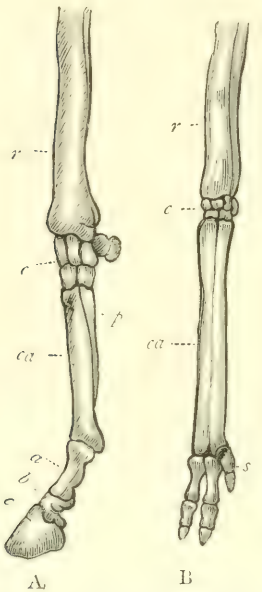


Fig. 595.—A, Fore-leg of the Horse: *r*, Radius; *c*, Carpus; *ca*, Canon-bone; *p*, Splint-bone; *a*, First phalanx or "great pastern;" *b*, Second phalanx or "small pastern;" *c*, Ungual phalanx or "coffin-bone." B, Fore-limb of a Deer: *r*, Radius; *c*, Carpus; *ca*, Canon-bone; *s*, One of the supplementary toes.

The metacarpus in Man and in most Mammals consists of five cylindrical bones, articulating proximally with the carpus, and distally with the phalanges of the fingers. The most remarkable modification of this normal state of things occurs in the Ruminants and in the Horse. In the Ruminants, in which the foot is cleft, and consists of two perfect toes only, there are two metacarpal bones in the embryo; but these are anchylosed together in the adult, and form a single mass which is known as the "canon-bone" (fig. 595, *ca*). In the Horse, in which the foot consists of no more than a single digit, there is only a single metacarpal bone, on each side of which are two little bony spines—the so-called "splint-bones"—which are attached superiorly to the carpus. These are to be regarded as rudimentary metacarpals. In most of the other Ungulates there are at least three metacarpals, and in the Elephants there are five.

The normal number of digits is five, but they vary from one to five. The middle finger is the longest and most persistent of the digits of the fore-limb; and in the Horse it is the only one which is left (fig. 595, A). The thumb is very frequently absent. In the Ruminants there are only two fingers which are functionally useful, these carrying the hoofs. In many Ruminants, however, there are two rudimentary and functionally useless digits in addition.

Normally each digit has three phalanges, except the thumb, which has only two. In the Whales and Dolphins (*Cetacea*), in which the anterior limbs form swimming-paddles very like those of the *Ichthyosaurus* and *Plesiosaurus*, the phalanges are considerably increased in number as they are in those Reptiles. In all the Mammalia, too, except the *Cetacea*, it is the rule that the terminal phalanx in each digit should carry a nail, claw, or hoof.

Whilst the anterior limbs are never absent in any Mammal, the posterior limbs are occasionally wholly wanting, as in the *Cetacea* and *Sirenia*. Generally speaking, however, the posterior limbs are present, and the pelvic arch has much the same structure as in man. The two halves of the pelvis —the ossa innominata—consist each of three pieces in the embryo (viz., the ilium, ischium, and pubes), which meet to form the cup-shaped cavity known as the "acetabulum," with which the head of the thigh-bone articulates. In the adult Mammal these three bones are anchylosed together, and the two ossa innominata unite in front by means of a symphysis pubis, constituted either by a cartilaginous union (synchondrosis), or by merely ligamentous attachment. In some Mammals, however, such as the Mole, and many of the Bats, the pubic bones remain disunited during life. As a rule, also, the ossa innominata are firmly united with the vertebral column. In the Cetaceans, in which the hind-limbs are wanting, and there is no sacrum, the innominate bones are rudimentary, and are not attached in any way to the spine.

The only other bones which are ever connected with the pelvis are two small bones which are directed upwards from the brim of the pelvic cavity in Marsupials and Monotremes. These are the so-called "marsupial bones," regarded gener-

ally as not forming parts of the skeleton properly so called, but as being ossifications of the internal tendons of the "external oblique" muscles of the abdomen (fig. 598).

In those Mammals which possess hind-limbs, the normal composition of the member is of the following parts: 1. A thigh-bone or femur; 2. Two bones forming the shank, and known as the tibia and fibula; 3. A number of small bones constituting the ankle or tarsus; 4. The "root" of the foot, made up of the "metatarsus;" 5. The phalanges of the toes (see fig. 483).

The thigh-bone or femur articulates with the pelvis, usually at a very open angle. In Man it is distinguished by being the longest bone of the body, and by having the axis of its shaft nearly parallel to that of the vertebral column. In most Mammals the femur is relatively shorter, and the axis of its shaft deviates considerably from that of the spine, being sometimes at right angles, or even at an acute angle.

Of the bones of the leg proper the tibia corresponds to the radius in the fore-limb, as shown by its carrying the tarsus; and the fibula is the representative of the ulna. The articulation between the tibia and fibula on the one hand, and the femur on the other, constitutes the "knee-joint," which is usually defended in front by the "knee-pan" or patella, a large sesamoid bone developed in the tendons of the great extensor muscles of the thigh. The patella is of small size in the *Carnivora*, but does not appear to be wanting in any except the Marsupials. In many cases the tibia and fibula are anchylosed towards their distal extremities. In the Horse the fibula has much the same character as in Birds, being a long splint-like bone which only extends about halfway down the tibia. In the Ruminants the reverse of this obtains, the upper half of the fibula being absent, and only the lower half present.

The tibia articulates with the tarsus, consisting in Man of seven bones, but varying in different Mammals from four to nine.

The foot consists normally of five toes connected with the tarsus by means of five metatarsal bones, which closely re-

semble the metacarpals. In the Ruminants there are only two metatarsals, and these are anchylosed in the adult, and carry two toes. In the Horse there is only one complete metatarsal supporting a single toe. As a rule, the number of digits in the hind-limb or foot is the same as that in the fore-limb or hand; but this is not always the case.

The cranial bones are invariably connected with one another by sutures, and in no other examples than the Monotremes are these sutures obliterated in the adult. The occipital bone carries two condyles for articulation with the first cervical vertebra. The lower jaw is composed of two halves or rami, which are distinct from one another in the embryo, and may or may not be anchylosed together in the adult. However this may be, in no Mammal is the ramus of the lower jaw composed of several pieces, as it is in Birds and Reptiles, nor does it articulate with the skull by the intervention of an os quadratum. On the other hand, each ramus of the lower jaw in the Mammals is composed of only a single piece, and articulates with the squamosal element of the skull, or, in other words, with the squamous portion of the temporal bone.

Teeth are present in the great majority of Mammals; but they are only present in the embryo of the Whalebone Whales, and are entirely absent in the genera *Echidna*, *Manis*, and *Myrmecophaga*. In the Duck-mole (*Ornithorhynchus*) the teeth are horny, and the same was the case in the extinct *Rhytina* amongst the *Sirenia*. In all other Mammals the teeth have their ordinary structure of dentine, enamel, and crusta petrosa or cement, these elements being variously disposed in different cases. In no Mammals are the teeth ever anchylosed with the jaw, and in all the teeth are implanted into distinct sockets or alveoli, which, however, are very imperfect in some of the Cetacea.

Many Mammals have only a single set of teeth throughout life, and these are termed by Owen "monophyodont." In most cases, however, the first set of teeth—called the "milk" or "deciduous" teeth—is replaced in the course of growth by a second set of "permanent" teeth. The deciduous and permanent sets of teeth do not necessarily correspond

to one another; but no Mammal has ever *more* than these two sets. The Mammals with two sets of teeth are called by Owen "diphyodont."

In Man and in many other Mammals the teeth are divisible into four distinct groups, which differ from one another in position, appearance, and function; and which are known respectively as the *incisors*, *canines*, *præmolars*, and *molars* (fig. 596). "Those teeth which are implanted in the præmaxillary bones, and in the corresponding part of the lower jaw, are called 'incisors,' whatever be their shape or size. The tooth in the maxillary bone which is situated at or near to the suture with the præmaxillary, is the 'canine,' as is also that tooth in the lower jaw which, in opposing it, passes in front of its crown when the mouth is closed. The other teeth of the first set are the 'deciduous molars;' the teeth

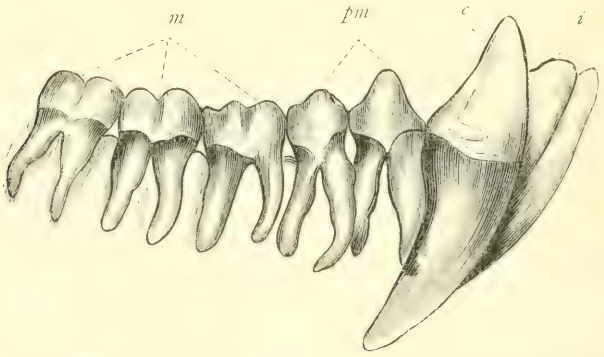


Fig. 596.—Teeth of the right side of the lower jaw of the Chimpanzee (after Owen).
i, Incisors; *c*, Canine; *pm*, Præmolars; *m*, Molars.

which displace and succeed them vertically are the 'præmolars;' the more posterior teeth, which are not displaced by vertical successors, are the 'molars' properly so called" (Owen). The deciduous dentition, therefore, of a diphyodont Mammal consists of only three kinds of teeth—incisors, canines, and molars. The incisor and canine teeth of the deciduous set are replaced by the teeth which bear the same names in the permanent set. The deciduous "molars," however, are replaced by the permanent "præmolars," and the "molars" of the permanent set of teeth are not represented

in the deciduous series, only existing once, and not being replaced by successors.

All these four kinds of teeth are not necessarily present in all Mammals, and, as will be afterwards seen, the characters of the teeth are amongst the most important of the distinctions by which the Mammalian orders are separated from one another. The variations which exist in the number of teeth in different Mammals are usually expressed by a "dental formula," which presents the "dentition" of both jaws in a condensed and easily-recognised form.

According to Owen, the typical permanent dentition of a diphyodont Mammal would be expressed by the following formula:—

$$i\,\frac{3—3}{3—3};\ c\,\frac{1—1}{1—1};\ pm\,\frac{4—4}{4—4};\ m\,\frac{3—3}{3—3}=44.$$

The four kinds of teeth are indicated in such a formula by the letters—incisors *i*, canines *c*, præmolars *pm*, molars *m*. The numbers in the upper line indicate the teeth in the upper jaw, those in the lower line stand for those in the lower jaw; and the number of teeth on each side of the jaw is indicated by the short dashes between the figures.

As regards their general *distribution in time*, as a matter of course, the remains of Mammals are scanty, and occupy but a small space in the geological record; since the greater number of the *Mammalia* are terrestrial, and the greater number of the stratified fossiliferous deposits are marine. The Mammals, too, are the most highly organised of the entire sub-kingdom of the *Vertebrata;* and therefore, in obedience to the well-known law of succession, they ought to make their appearance upon the globe at a later period than any of the lower classes of the *Vertebrata*. Such, in point of fact, is to a great extent the case; and if the geological record were perfect, the law would doubtless be carried out to its full extent.

It is in the upper portion of the Triassic rocks—that is to say, not long after the commencement of the Mesozoic or Secondary epoch—that Mammals for the first time make their appearance; three or four species being now known in

a zone of rocks which are placed at the summit of the Trias, just where this formation begins to pass into the Lias. The earliest of these—the oldest known of all the Mammals—appears at the upper part of the Upper Trias (Keuper) and also at its very summit (Penarth beds), and has been described under the name of *Microlestes antiquus*. The nearest ally of *Microlestes* amongst existing Mammals would seem to be the Marsupial and insectivorous *Myrmecobius*, or Banded Ant-eater, of Australia. As only the teeth, however, of *Microlestes* have hitherto been discovered, it is impossible to decide positively whether this primeval Mammal was Marsupial or Placental. In the North American area, also, the first traces of Mammals (*Dromatherium*) appear in the Trias.

The next traces of Mammals occur in the Stonesfield Slate (Lower Oolites), and here four species, all of small size, are known to occur. Most of these were Marsupial, but it is possible that one was Placental. They form the genera *Amphilestes*, *Amphitherium*, *Phascolotherium*, and *Stereognathus*. After the Stonesfield Slate another interval succeeds, in which no Mammalian remains have hitherto been found; but in the fresh-water formation of the Middle Purbeck, at the top, namely, of the Oolitic series, as many as fourteen small Mammals have been discovered. These constitute the genera *Plagiaulax*, *Spalacotherium*, *Triconodon*, and *Galestes*. The Upper Jurassic of North America has also yielded a small Opossum. Another gap then follows, no Mammal having hitherto been discovered in any portion of the Cretaceous series (with doubtful exceptions).

Leaving the Mesozoic and entering upon the Kainozoic period, remains of Mammals are never absent from any of the geological formations. From the base of the Eocene rocks up to the present day remains of Mammals commonly occur, constantly increasing in number and importance, till we arrive at the fauna now in existence upon the globe.

It should be noticed, further, that there are many points in which it can be demonstrated that the earlier Tertiary Mammals were of a more generalised type than those now existing, and in particular groups a very well marked pro-

gressive specialisation can be traced as we approach the present day. Thus the Eocene Mammalia very commonly possessed the full typical number of twenty-two teeth in each of the jaws, and these teeth were more uniform in size, less conspicuously differentiated into groups, and more closely approximated to one another than in most of the later forms. In the older forms, further, the molars were usually short-crowned, and we can trace a progressive lengthening of the crowns of these teeth, in the course of time, this conditioning a greater capacity to resist attrition, and a consequent suitability in their possessor for a more prolonged life. In other cases, we can trace a gradual and progressive stunting or abortion of the lateral digits of the typical five-toed limb, accompanied by a correspondingly progressive elongation and strengthening of the central and remaining digits. Lastly, it can be shown that there has been in many instances a progressive increase in the size of the brain, as we approach the present day. Most of the Eocene Mammals, in which the cranium is known, possessed brains of very small size in proportion to the bulk of the body; and this disproportion gradually lessens as we pass through the Miocene and Pliocene to the Recent period.

In the following are given the characters of each order of the *Mammalia*, with the range in time, and, so far as known, the more important fossil forms of each. The number, however, of known fossil Mammals is so great, and in many cases they exhibit so many peculiarities and divergences from existing forms, that nothing more can be attempted here than to give a brief and general sketch of the palæontological history of the class; attention being drawn, where it may seem necessary, to extinct types of special interest.

CHAPTER XXXIX.

ORDERS OF MAMMALIA.

Monotremata and Marsupialia.

Order I. Monotremata.—The first and lowest order of the *Mammalia* is that of the *Monotremata*, containing only two genera, both belonging to Australia—namely, the Duck-moles (*Ornithorhynchus*) and the Porcupine Ant-eaters (*Echidna*).

The order is distinguished by the following characters: *The intestine opens into a "cloaca," which receives also the products of the urinary and generative organs, which discharge themselves into a urogenital canal*—the condition of parts being very much the same as in Birds. *The jaws are either wholly destitute of teeth* (Echidna) *or are furnished with four horny plates which act as teeth* (Ornithorhynchus). *The pectoral arch has some highly bird-like characters, the most important of these being the extension of the coracoid bones to the anterior end of the sternum. An interclavicle is also present. The females possess no marsupial pouch, but the pelvis is furnished with the so-called "marsupial bones," being special ossifications of the internal tendons of the external oblique muscles of the abdomen. The mammary glands have no nipples, and their ducts open either into a kind of integumentary pouch* (Echidna) *or simply on a flat surface* (Ornithorhynchus). *The young are destitute of a placenta, or, in other words, no vascular connection is established between the fœtus and the mother.* The feet have five toes each, armed with claws, and the males carry perforated spurs on the back of the tarsus (attached to a supplementary tarsal bone).

The two living genera *Ornithorhynchus* and *Echidna*, which alone comprise this order, are exclusively confined to the Australian province, and possess some remarkable peculiarities of structure. The most important of these, as regards the skeleton, concern the condition of the pectoral arch. Thus the coracoids reach the top of the sternum, with which they articulate; while there is a large T-shaped "interclavicle," or "episternum" (fig. 597, *i*), which supports the clavicles. The condition of the pectoral arch thus reminds one of that which obtains in the Birds and many of the Reptiles.

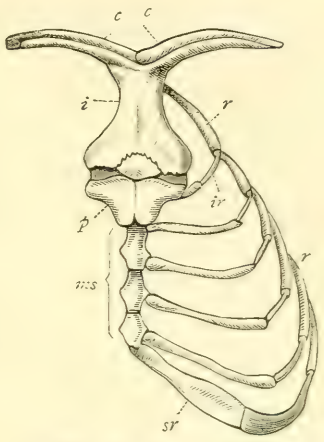


Fig. 597.—Sternum and adjacent parts of the skeleton of a young *Ornithorhynchus* (after Flower): *c*, *c*, Clavicles; *i*, Interclavicle; *p*, Præsternum; *ms*, Mesosternum; *r*, *r*, Vertebral ribs; *ir*, Intermediate ribs; *sr*, Sternal ribs.

Palæontologically, the interest of the Monotremes is chiefly theoretical; since the only fossil remains referable to this order that have hitherto been discovered, are those of a gigantic *Echidna*, recorded by Mr Krefft as occurring in the Post-Tertiary deposits of Australia.

Order II. Marsupialia. — The order *Marsupialia* forms with the *Monotremata* the division of the Non-placental Mammals. With the single exception of the family *Didelphidæ*, which is American, all the living *Marsupialia* belong to the Melanesian province—that is to say, they all belong to Australia, Van Diemen's Land, New Guinea, and some of the neighbouring islands.

The following are the characters which distinguish the order:—

The skull is composed of distinct cranial bones united by sutures, and they all possess true teeth; whilst the angle of the lower jaw is almost always inflected. The pectoral arch has the same form as in the higher Mammals, and the coracoid no longer reaches the anterior end of the sternum. All possess the

so-called "marsupial bones," attached to the brim of the pelvis. The corpus callosum is very small, and has been asserted to be absent. The young Marsupials are born in a very imperfect condition, of very small size, and at a stage when their development has proceeded to a very limited degree only. There is no placenta or vascular communication between the mother and fœtus, parturition taking place before any necessity arises for such an arrangement. As the young are born in such an imperfect state of development, special arrangements are required to secure their existence. When born, they are therefore, in the great majority of cases, transferred by the mother to a peculiar pouch formed by a folding of the integument of the abdomen. This pouch is known as the "marsupium," and gives the name to the order. Within the marsupium are contained the nipples, which are of great length. Being for some time after their birth extremely feeble, and unable to perform the act of suction, the young within the pouch are nourished involuntarily, the mammary glands being provided with special muscles which force the milk into the mouths of the young. At a later stage the young can suckle by their own exertions, and they leave the pouch and return to it at will. In a few forms there is no complete marsupium as above described; but the structure of the nipples is the same, and the young are carried about by the mother, adhering to the lengthy teats.

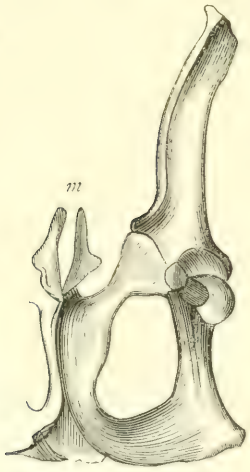


Fig. 598.—One side of the pelvis of a Kangaroo, showing the "marsupial bones" (*m*). After Owen.

The so-called "marsupial bones" (fig. 598) doubtless serve to support the marsupial pouch and its contained young, but this cannot be their sole function, since they occur in the Monotremes, in which there is no pouch. They consist of two small bones, which spring from the brim of the pelvis, and which are merely ossifications of the internal tendons of the "external oblique" muscles of the abdomen.

The *Marsupialia* are divided by Owen into the two primary groups of the *Diprotodontia* and *Polyprotodontia*, in accordance with the condition of the incisor teeth. In the Diprotodont forms (fig. 599, A) there are only two lower incisors, canines are rudimentary or wholly wanting; and the molars mostly have broad grinding crowns. The living members of this group—such as the Kangaroos (*Macropodidæ*), the Wombat (*Phascolomys*), the Kangaroo-rats (*Hypsiprymnus*), and the Phalangers (*Phalangistidæ*)—are all herbivorous; and

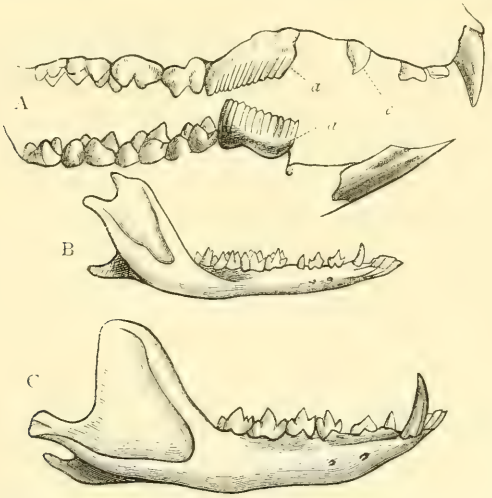


Fig. 599.—A, Dentition of a Diprotodont Marsupial (*Hypsiprymnus cuniculus*), showing the upper canine (*c*) and the great grooved first præmolar (*a*, *a*); B, Lower jaw of an entomophagous Polyprotodont Marsupial (*Perameles obesula*); C, Lower jaw of a predatory Polyprotodont Marsupial (*Dasyurus ursinus*). (After Giebel and Waterhouse.)

this is the case with the great majority of the fossil forms, though Prof. Owen is of opinion that some of the latter were carnivorous in habit. In the Polyprotodont Marsupials—such as the living Bandicoots (*Perameles*), Opossums (*Didelphidæ*), the Banded Ant-eater (*Myrmecobius*), the *Dasyurus*, and the *Thylacinus*—there are always more than two lower incisors (fig. 599, B and C), the canines are more or less extensively developed, and the molars are either cuspidate or have sectorial crowns. All the members of this section are essentially carnivorous, feeding upon insects or upon the

smaller vertebrate animals; and the same holds good of all the fossil forms.

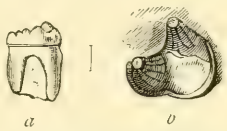
As regards their distribution in time, the *Marsupialia* probably constitute the oldest of the Mammalian orders. Owing, however, to the detached and fragmentary condition of almost all Mammalian remains—consisting in many cases of the ramus of the lower jaw, or of separate teeth—it is not possible to state this with absolute certainty. The oldest known European Mammal is the *Microlestes antiquus* (fig. 602) of the Upper Trias, only a few teeth of which have been as yet detected. The earliest horizon on which *Microlestes* occurs is in a "bone-bed" in the Keuper of Würtemberg; but it has also been detected in the higher "Rhætic" beds. Prof. Owen believes that the *Hypsiprymnopsis* of Mr Boyd Dawkins, from the Rhætic marls of Somersetshire, is also referable to *Microlestes*. Upon the whole, it is most probable that *Microlestes* was Marsupial; and it appears to be most nearly related to the little insectivorous *Myrmecobius* or Banded Ant-eater of New South Wales (fig. 600).

Fig. 600.—*Myrmecobius fasciatus.*

Nearly allied to *Microlestes* is a small Mammal, a lower jaw of which has been obtained from the Trias of North America, and which has been described under the name of *Dromatherium sylvestre*. This little animal (fig. 601) appears also to be Marsupial, and to be most nearly related

to *Myrmecobius*. Each ramus of the lower jaw contains "ten small molars in a continuous series, one canine, and

Fig. 601.—Lower jaw of *Dromatherium sylvestre*. Trias, North Carolina. (After Emmons.)



a *b*

Fig. 602.—*a*, Molar tooth of *Microlestes antiquus*, magnified; *b*, Crown of the same, magnified still further. Trias, Germany.

three conical incisors—the latter being divided by short intervals" (Owen).

The next Mammaliferous horizon above the Trias is the Stonesfield Slate in the Lower Oolites; and there is no doubt that some, if not all, of the Mammalian remains of this belong to small Marsupials. Four genera of small Mammals are known from this horizon—viz., *Amphilestes*, *Amphitherium*, *Phascolotherium*, and *Stereognathus*. In *Amphitherium* (fig. 603) the molars are cuspidate, and the animal was doubtless insectivorous. It is believed by Owen to be Marsupial, and to be most nearly related to *Myrmecobius*. *Amphilestes* and *Phascolotherium* (fig. 604, 1) are also believed by the same high authority to have been insectivorous Marsupials, and the latter is supposed to find its nearest living ally in the Opossums of America. Lastly, the *Stereognathus* of the Stonesfield Slate is in a dubious position. It may have been Marsupial; but, upon the whole, Prof. Owen is inclined to believe that it was placental, hoofed, and herbivorous.

Fig. 603.—Ramus of the lower jaw of *Amphitherium* (*Thylacotherium*) *Prevostii*. Stonesfield Slate.

With the occurrence of small Marsupials in England within the Oolitic period, it is interesting to notice how the fauna of that time approached in other respects to that now inhabiting Australia. At the present day, Australia is almost wholly tenanted by Marsupials; upon its land-surface flourish *Araucariæ* and Cycadaceous plants, and in its seas

swims the Port-Jackson Shark (*Cestracion Philippi*); whilst the Molluscan genus *Trigonia* is nowadays exclusively confined to the Australian coasts. In England at the time of the deposition of the Stonesfield Slate, we must have had a fauna and flora very closely resembling what we now see in Australia. The small Marsupials *Amphitherium* and *Phascolotherium* prove that the Mammals were the same in order; cones of Araucarian pines, with tree-ferns and fronds of Cycads, occur throughout the Oolitic series; spine-bearing fishes, like the Port-Jackson Shark, are abundantly represented by genera such as *Acrodus* and *Strophodus;* and lastly, the genus *Trigonia,* now exclusively Australian, is represented in the Stonesfield Slate by species which differ little from those now existing.

Another singular point of resemblance is established by the occurrence in the rivers of Queensland of the "Barramunda," which is referred to the genus *Ceratodus*—a genus which, though pre-eminently Triassic, nevertheless extended its range into the Jurassic period.

Towards the close of the Oolitic period, in the Middle Purbeck beds, we have evidence of a number of small Mammals, all of which are probably referable to the *Marsupialia*, and all of which, except *Plagiaulax,* are Polyprotodont. Fourteen species are known, all of small size, the largest being no bigger than a polecat or hedgehog. The genera to which these little quadrupeds have been referred are *Plagiaulax, Spalacotherium, Triconodon,* and *Galestes.* The first of these—viz., *Plagiaulax* (figs. 604 and 605)—is believed to be most nearly allied to the living Kangaroo-rats (*Hypsiprymnus*) of Australia; and it is held by good authorities to have been phytophagous, as are its living relatives. Prof. Owen, on the other hand, believes that *Plagiaulax* was carnivorous. The chief feature in the dentition of *Plagiaulax* is found in the fact that the præmolars are marked on the exterior of their crowns with seven conspicuous grooves (fig. 605, A and B), which entirely resemble the grooves in the large first præmolar of the living *Hypsiprymnus,* except that they are diagonal and not vertical in direction. The lower incisors have an upward curvature, which is not the

case with the ordinary Diprotodont Marsupials; and the molars are very similar in type to those of *Microlestes*. The remaining three genera of the Purbeck beds—viz., *Spalacotherium*, *Triconodon* (fig. 604, 2), and *Galestes*—ap-

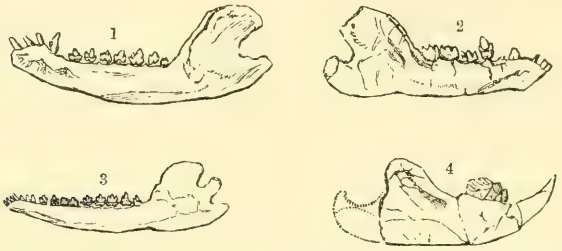


Fig. 604.—Oolitic Mammals, natural size. 1, Lower jaw and teeth of *Phascolotherium*: 2, of *Triconodon*; 3, of *Amphitherium*; 4, of *Plagiaulax*.

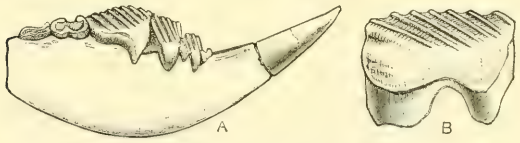


Fig. 605.—A, Right ramus of lower jaw of *Plagiaulax minor*—Jurassic, enlarged four diameters; B, Third præmolar of *Plagiaulax Becklesii*, enlarged five and a half times, and showing the diagonal grooves on the exterior of the crown. (After Owen.)

pear to have been certainly insectivorous, and find their nearest living allies in the Australian Phalangers and the American Opossums.

In the North American area, the earliest known remains of Marsupials have been obtained by Professor Marsh from beds of Upper Jurassic age. These indicate the existence of a small Opossum (*Dryolestes priscus*), belonging to the family of the *Didelphidæ*, and thus of special interest as showing that this peculiarly American type was differentiated at a date so comparatively early, within the same geographical region as that in which it now occurs.

Coming next to the Tertiary deposits, we find that few traces of this order have been as yet discovered. In the Eocene Tertiary of the Paris basin, we meet with true Opossums (*Didelphidæ*), closely resembling the existing American species of *Didelphys*, though the distinct genus *Peratherium*

has been constituted for their reception, on account of some subordinate peculiarities in their dentition. Several very similar forms have been described from the Miocene; but no undoubted Marsupials have been as yet detected in the Pliocene deposits.

In the Post-Tertiary period, on the other hand, the order of the *Marsupialia* is represented by some very remarkable forms. The most important of the remains in question have been found in the bone-caves of Australia—the country in which Marsupials now abound above every other part of the globe; and they show that Australia, at no distant geological period, possessed a Marsupial fauna, much resembling that which it has at present, but of forms comparatively of gigantic size. In the remains from the Australian bone-caves, almost all the most characteristic living Marsupials of Australia and Van Diemen's Land are represented; but the extinct forms are usually of much larger dimensions. The group of Marsupials (*Fossoria*) represented by the living Wombat (*Phascolomys*) is represented in this way by congeneric Tertiary forms, which must have equalled the Tapir in size. This genus (fig. 606) belongs to the Diprotodont division of the Marsupials, but the incisors have the peculiarity—otherwise unknown in the order—that they grow

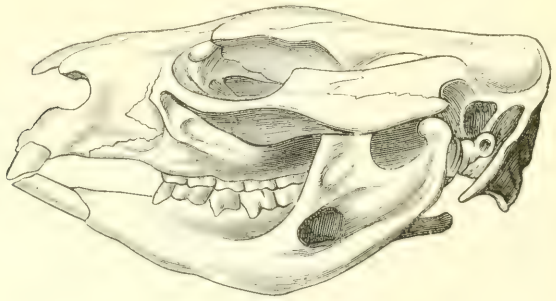


Fig. 606.—Skull of Wombat. (After Giebel.)

from persistent pulps, in this respect resembling the incisors of the Rodents. Canines are wholly wanting and the dental formula is—

$$i\ \frac{1—1}{1—1};\ c\ \frac{0—0}{0—0};\ pm\ \frac{1—1}{1—1};\ m\ \frac{4—4}{4—4} = 24.$$

A second great group of the Diprotodont Marsupials is represented at the present day by the existing Kangaroos (*Macropus*) and Kangaroo-rats (*Hypsiprymnus*). In this group the hind-legs are longer than the fore-legs; the lower incisors are nearly horizontal, and are rooted (fig. 599, A, and fig. 607); and there are no canines.

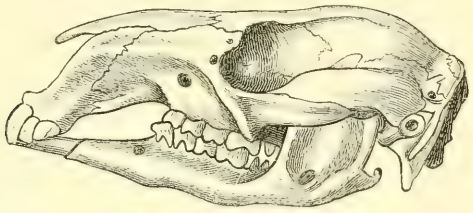


Fig. 607.—Skull of the living *Macropus Bennetti*. (After Giebel.)

The dental formula of the Kangaroos is—

$$i\ \frac{3—3}{1—1};\ c\ \frac{0—0}{0—0};\ pm\ \frac{1—1}{1—1};\ m\ \frac{4—4}{4—4} = 28.$$

The living genus *Macropus* is represented in the Post-Tertiary deposits of Australia by species in all essential respects agreeing with the recent forms but of gigantic size, one species being as large as the Rhinoceros. The *Sthenurus* and *Protemnodon* of the same deposits are related, on the other hand, to the Tree-kangaroos (*Dendrolagus*) of New Guinea. Associated with these extinct types of Kangaroos, we have also representatives of the smaller Kangaroo-rats (*Hypsiprymnus* and *Bettongia*).

A third group of Diprotodonts is represented in the Post-Tertiary of Australia by the extraordinary extinct types *Diprotodon* and *Nototherium*, which were vegetable-feeders, like the living Kangaroos, but present certain peculiarities of their own. In *Diprotodon* (fig. 608) the two lower incisors are round and tusk-like, and there are six upper incisors, of which the two median ones are of large size, curved, and

chisel-shaped. The incisors differ from those of the Kangaroos, and agree with those of the Wombats, in growing from persistent pulps; there are no canines; there is a single

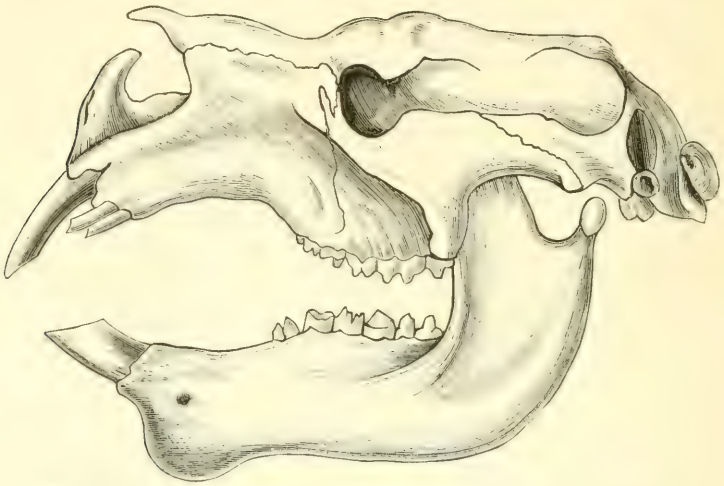


Fig. 608.—Skull of *Diprotodon Australis*. (After Owen.) Post-Tertiary, Australia.

small præmolar, which is lost in aged animals; and there are four grinding molars on each side of each jaw. The dental formula is—

$$i\ \frac{3—3}{1—1};\ c\ \frac{0—0}{0—0};\ pm\ \frac{1—1}{1—1};\ m\ \frac{4—4}{4—4} = 28.$$

The fore-limbs appear to have been about equal in size to the hind-limbs, and the mode of progression must have been quite unlike that which obtains in the Kangaroos. In size, also, *Diprotodon* must have many times exceeded the largest of the living Kangaroos, since the skull measures three feet in length.

Nototherium (*Zygomaturus*) resembles *Diprotodon* in some respects; but the lower incisors are diminutive, and all the front teeth are rooted.

Lastly, there is a group of Diprotodonts in which we have only the singular extinct genus *Thylacoleo* (fig. 609), in which the most prominent feature of the dentition is the

presence in either jaw of a huge, compressed, and trenchant præmolar. The dental formula is—

$$i\,\frac{1—1}{3—3};\ c\,\frac{1—1}{0—0};\ pm\,\frac{3—3}{1—1};\ m\,\frac{1—1}{2—2}=24.$$

The incisors are not horizontal, as in the Kangaroos, but resemble those of the Phalangers, and the true molars are very small. Nothing is known of the skeleton of *Thylacoleo* beyond the skull; and the peculiar dentition has been differently interpreted by different authorities. By Professor Owen it is believed that *Thylacoleo* was flesh-eating and predatory in its habits, and that it represents a type of Dipro-

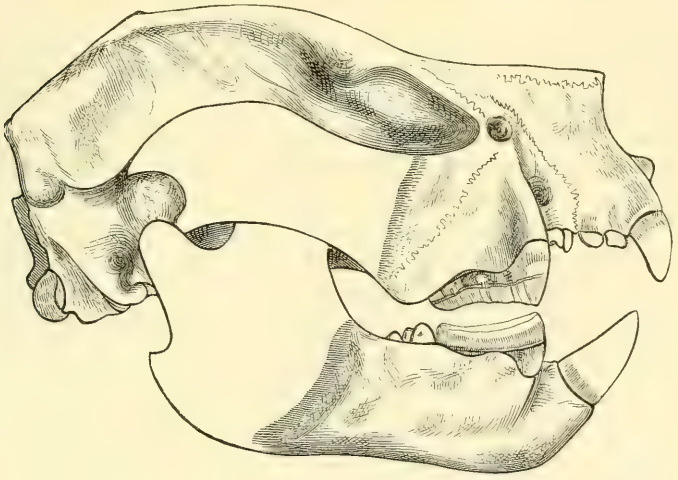


Fig. 609.—Skull of *Thylacoleo*. Post-Tertiary deposits of Australia. (After Flower.)

todonts specially modified in accordance with the carnivorous mode of life. Professor Flower, on the other hand, compares the cutting præmolar with the correspondingly developed tooth in *Hypsiprymnus*, and concludes that "*Thylacoleo* is a highly-modified and aberrant form of the type of Marsupials now represented by the *Macropodidæ* and *Phalangistidæ*, though not belonging to either of these families as now restricted," and he believes that its diet was of a vegetable nature. Under any view of its habits, *Thylacoleo* is a

very remarkable type of the Marsupials; and it must have attained a very great size, since the length of the crown of the great præmolar is not less than two inches and a quarter.

Just as the living Kangaroos and Wombats of the Australian province find Post-Tertiary representatives within the same geographical region, so also do we find that the Polyprotodont Marsupials existed side by side with the preceding. Moreover, the Post-Tertiary Polyprotodonts belong to types which still exist in Australia, and which are peculiar to it. Thus the living Bandicoots (*Perameles*) have their Post-Tertiary representatives; and the more highly carnivorous and predatory *Thylacinus* and *Dasyurus* of Van Diemen's Land were preceded by closely allied forms, which ranged over the mainland of Australia.

Precisely parallel phenomena are observable in North and South America, all the living Marsupials of which belong to the Polyprotodont family of the Opossums (*Didelphidæ*). Apart from the early appearance of this Marsupial type in the previously-mentioned *Dryolestes* of the North American Jurassic, the Post-Pliocene deposits of the same continent have yielded bones actually referable to the living genus *Didelphys*. In South America, also, the Post-Pliocene cave-deposits of Brazil have yielded various species of the same genus. These examples, then, afford a very striking illustration of the general law that the Post-Tertiary Mammals of a given country belong in a general way to types of structure represented in the same region at the present day by forms often generically different.

CHAPTER XL.

ORDERS OF MAMMALIA (Continued).

Edentata.

Order III. Edentata or Bruta.—The lowest order of the placental or monodelphous Mammals is that of the *Edentata*, often known by the name of *Bruta*. The name *Edentata* is certainly not an altogether appropriate one, since it is only in two genera in the order that there are absolutely no teeth. The remaining members of the order have teeth, but these are *always destitute of true enamel, are never displaced by a second set, and have no complete roots. Further, in none of the Edentata are there any median incisors, and in only one species (one of the Armadillos) are there any incisor teeth at all. Canine teeth, too, are almost invariably wanting. Clavicles are usually present, but are absent in the Scaly Ant-eater (Manis). All the toes are furnished with long and powerful claws. The skin is often covered with bony plates or horny scales.*

The order *Edentata* is conveniently divided into two great sections, in accordance with the nature of the food, the one section being phytophagous, the other insectivorous. In the former section is the single living group of the Sloths (*Bradypodidæ*). In the latter are the two groups of the Armadillos (*Dasypodidæ*), and the various species of Ant-eaters (the latter constituting Owen's group of the *Edentula*).

The Edentates, like the Marsupials, are singularly circumscribed at the present day. No member of the order is at the present time indigenous in Europe. Tropical Asia

and Africa have the Scaly Ant-eaters or Pangolins; and in Africa occurs the Edentate genus *Orycteropus*. South America, however, is the metropolis of the *Edentata*, the

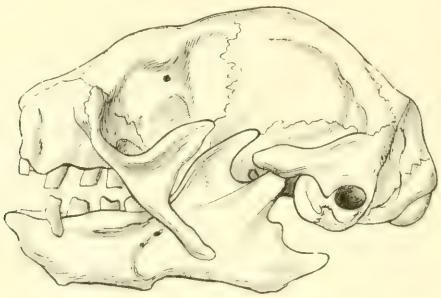


Fig. 610.—Skull of a living Sloth (*Bradypus cuculliger*). (After Giebel.)

order being there represented by the Sloths, the Armadillos, and the true Ant-eaters. It is also in South America that by far the greater number of extinct Edentates have been found; and, as in the case of the Australian Marsupials, the fossil forms are gigantic in size as compared with their living representatives.

The oldest well-known representative of the *Edentata* is the *Macrotherium* of the Miocene Tertiary of France. This is a gigantic Edentate, intermediate in some respects between the Pangolins (*Manis*) and the Aardwark (*Orycteropus*). There does not appear to have been any dermal armour, and the teeth are rootless and destitute of enamel. The toes were furnished with immense claws, which were bent inwards upon the palms of the hands and soles of the feet, in consequence of the flexion of the first phalanges upon the metacarpals and metatarsals. The animal, therefore, doubtless walked, like the existing Ant-eaters (*Myrmecophaga*), upon the outer sides of the feet. The hind-limbs were much shorter than the fore-limbs, which to some extent would support the view that the animal was a climber; but its great size would render it unlikely that the habits of the genus were arboreal.

Another ancient genus of Edentates is the *Ancylotherium* of M. Gaudry. Phalanges, apparently referable to a species

of this genus (*A. priscum*) have been found in deposits which are believed to be of Eocene age. More thoroughly known, however, is the *Ancylotherium Pentelici* of the Miocene [1] deposits of Pikermi in Greece. This singular form was of gigantic dimensions, and the structure of the feet was much the same as in *Macrotherium;* but the hind-limbs nearly equalled the fore-limbs in length, and the animal must have been terrestrial in its habits.

The forms already alluded to are the only Edentates which have hitherto been discovered in the European area, and they belong to types which cannot be paralleled precisely with any at present in existence. In the Western hemisphere the first traces of Edentates detected up to this time date from the Miocene Tertiary. In beds of this age on the Pacific coast of North America, have been found the remains of two species of gigantic Edentates, which have been referred to the genus *Moropus*. Another species of the same genus occurs in the Lower Pliocene of Nebraska; and the genus itself is regarded as the type of a peculiar family of Edentates, to which the name of *Moropodidæ* has been given. In the Lower Pliocene of Idaho and California there have also been found remains of another extinct genus—*Morotherium*—comprising large Edentates, which seem to be early representatives of the wonderful American family of the "Gravigrade" Sloths, to be spoken of immediately.

It is, however, in the late Pliocene, and more particularly the Post-Pliocene, deposits of the New World that we find proofs of the past existence of the most numerous and remarkable of the fossil *Edentata*—many of these being referable to families now existing in the same area. The most remarkable of the extinct types in question belong to the great group of the "Ground-sloths" or "Gravigrade" Edentates, which have no direct representatives at the present day, though they have many points of affinity to the living group of the Sloths (*Bradypodidæ*) of South America. The latter are entirely arboreal in their habits, and are not only adapted for a life of climbing, but are all comparatively small

[1] The Pikermi deposits are believed by some palæontologists to be properly referable to the Pliocene.

animals. The former, on the other hand, though in many respects similarly constructed, and likewise vegetable-feeders, were of gigantic size, and must have lived exclusively upon the ground. The most celebrated of these great *Gravigrada* is the genus *Megatherium*, of which *M. Cuvieri* (fig. 611) of the South American Pampas may be taken as the type. This species comprised colossal Sloth-like animals, which

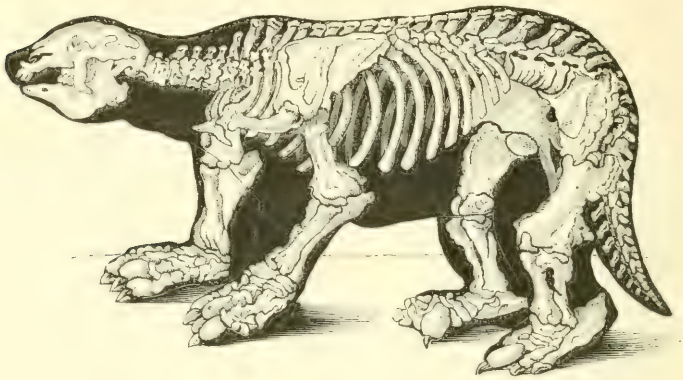


Fig. 611.—*Megatherium Cuvieri*. Post-Pliocene, South America.

attained a length of from twelve to eighteen feet, with bones more massive than those of the Elephant. Thus the thigh-bone is nearly thrice the thickness of the same bone in the largest of existing Elephants, its circumference at its narrowest point nearly equalling its total length; the massive bones of the shank (tibia and fibula) are amalgamated at their extremities; the calcaneum is nearly half a yard in length; the haunch-bones (ilia) are from four to five feet across at their crests; and the bodies of the vertebræ at the root of the tail are from five to seven inches in diameter, from which it has been computed that the circumference of the tail at this part might have been from five to six feet. The length of the fore-foot is about a yard, and the toes are armed with powerful curved claws, which are not developed on the fifth digit; while the pollex is wanting in the hand, and the hallux and index in the foot. It is known now that the Megathere, in spite of its enormous weight and ponder-

ous construction, walked, like the existing Ant-eaters and Sloths, upon the outside edge of the fore-feet, with the claws more or less bent inwards towards the palm of the hand. The skull is small, as is the brain-case proper; and the zygoma has a strong descending process, similar to that of the same bone in the true Sloths (fig. 610). As in the great majority of the Edentate order, incisor and canine teeth are entirely wanting, the front of the jaws being toothless. The jaws, however, are furnished with five upper and four lower molar teeth on each side. These grinding teeth are from seven to eight inches in length, in the form of four-sided prisms, the crowns of which are provided with well-marked transverse ridges; and they continue to grow during the whole life of the animal. There are indications that the snout was prolonged, and more or less flexible; and the tongue was probably prehensile. From the characters of the molar teeth it is certain that the Megathere was purely herbivorous in its habits; and from the enormous size and weight of the body it is equally certain that it could not have imitated its modern allies, the Sloths, in the feat of climbing, back downwards, amongst the trees. It is clear, therefore, that the Megathere sought its sustenance upon the ground; and it was originally supposed to have lived upon roots. By a masterly piece of deductive reasoning, however, Professor Owen showed that this great "Ground-sloth" must have truly lived upon the foliage of trees, like the existing Sloths —but with this difference, that instead of climbing amongst the branches, it actually uprooted the tree bodily. In this *tour de force*, the animal sat upon its huge haunches and mighty tail, as on a tripod, and then grasping the trunk with its powerful arms, either wrenched it up by the roots or broke it short off above the ground. Marvellous as this may seem, it can be shown that every detail in the skeleton of the Megathere accords with the supposition that it obtained its food in this way. Though principally South American, the genus *Megatherium* extended its range to North America, this continent having yielded the remains of a species closely allied to, or absolutely identical with, *M. Cuvieri*.

The genus *Mylodon* comprises large Sloth-like animals, of

which the best known is the *Mylodon robustus* (fig. 612). In its size, *Mylodon robustus* was smaller than the *Megatherium*, but it reached a length of eleven feet. In many respects *Mylodon* is very like *Megatherium*, and the number of the teeth is the same—viz., five upper and four lower molars on each side. The crowns of the molars, however, were flat,

Fig. 612.—Skeleton of *Mylodon robustus*. Post-Pliocene, South America.

instead of being ridged, and the anterior upper molars were separated by a gap from those behind them. The fore-feet are pentadactylous, and the posterior tetradactylous, the two external digits being nailless. Like *Megatherium*, the genus *Mylodon* is known to have ranged into North America.

Scelidotherium is another South American genus, closely allied to *Mylodon*, but comprising forms of smaller size and less massive construction, while the skull was elongated in shape, and other osteological differences existed as well.

Megalonyx, again, comprises large Sloth-like Edentates from the Post-Pliocene of North America. It has the same dental formula as *Megatherium* and *Mylodon*, but the crowns of the molars are excavated centrally and have a prominent margin,

while the first molar is large, pointed, and separated from those behind it by a wide gap. The fore-limbs are shorter than the hind-limbs, and the calcaneum is excessively long. In the Pliocene or Post-Pliocene deposits of Cuba occur the remains of the genera *Megalocnus* and *Myomorphus*, which are nearly allied to *Megalonyx*.

The great Ground-sloths, of which the principal types have now been briefly glanced at, not only have no representatives at the present day, but do not even appear, so far as certainly known, to have survived into the earlier portion of the Recent period, their last recorded occurrence being in the bone-caves of Brazil. On the other hand, it is in the deposits of these caves that we first meet with remains of the existing Sloths (*Bradypodidæ*), which make their appearance here under various extinct types, such as *Cœlodon* and *Ochotherium*.

The living families of the *Dasypodidæ* and *Myrmecophagidæ*, both characteristic of South America, were represented, similarly, by numerous interesting types which flourished in the same geographical area during late Pliocene and Post-Pliocene times. Most of these types, though clearly representative of those now existent, differed from the latter in points of generic importance, while many were of comparatively gigantic dimensions. Thus, side by side with the huge Megatheroids which took the place of the existing herbivorous Sloths, we find the colossal *Glyptodons*, representing the little banded and cuirassed Armadillos (*Dasypodidæ*) of the South America of to-day, and, like these, adapted for a carnivorous diet. Taking *Glyptodon* itself (fig. 613) as the type of this singular group of extinct Armadillos, we are presented with a large Edentate, the upper surface of which was protected by an armour formed of dermal ossifications or scutes. The head is covered with a helmet of bony plates, and the tail was enclosed in a complete cylindrical casing similarly composed. The trunk-armour is formed of nearly hexagonal bony scutes, forming a massive dome, for the support of which the skeleton is specially modified. Thus the last cervical and first two dorsal vertebræ are anchylosed to form a single bone

("trivertebral bone" of Huxley), which articulates by a movable hinge-joint with the remaining dorsal vertebræ, which are likewise anchylosed to form a kind of "tunnel or arched bridge of bone." The last two lumbar vertebræ are also fused with the sacral and caudal to form a contin-

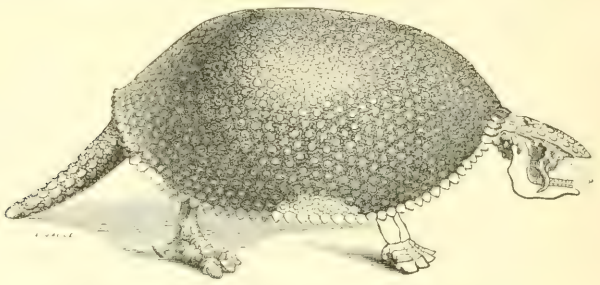


Fig. 613.—*Glyptodon clavipes* Post Pliocene, South America.

uous bony mass, whilst the ilia are of enormous size. Unlike the living Armadillos, *Glyptodon* possesses no movable bands in its armour, the scutes—which are characteristically sculptured in the different species — being in contact by their edges, though not anchylosed. The animal, therefore, possessed no power of rolling itself up for defence against its enemies.

There are no canine or incisor teeth in *Glyptodon*, but there are eight molars on each side of each jaw, and the crowns of these (fig. 614) are fluted and almost trilobed. The teeth form a continuous series, each being long, arched, and deeply furrowed with two parallel grooves on each side; and all grew from permanent pulps. The feet are massive, and the ungual phalanges are short, compressed, and hoof-like—the fore-feet being tetradactylous, and the hind-feet with four or five toes. The length of *Glyptodon clavipes* (fig. 613), from the tip of the snout to the end of the tail, was more than nine feet.

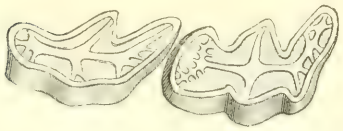


Fig. 614.—First and second molars of *Glyptodon asper*, viewed from above. (After Burmeister).

The genus *Schistopleurum* comprises gigantic Armadillos

which occur in South America along with *Glyptodon*. *Schistopleurum typus* was eight feet long, including the tail; and the carapace is three feet in height.

No direct representatives of the *Glyptodons* are known to exist at the present day; but the true Armadillos (fig. 615), with a variable number of movable bands in their dorsal armour, appear in both the late Pliocene or Post-Tertiary accumulations of the great plains of South America and also in the cave-deposits of Brazil. Some of these forms belong to well-known living generic or sub-generic types, such as

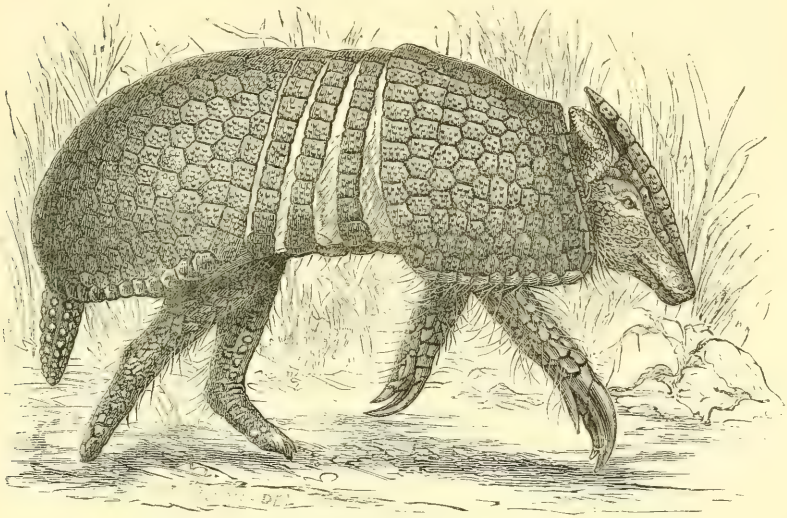


Fig. 615.—The living three-banded Armadillo (*Tolypeutes conurus*), one-third of the natural size. (After Murie.)

Dasypus, *Xenurus*, and *Eutatus*; while others are referable to extinct and comparatively gigantic forms, such as *Chlamydotherium*, *Pachytherium*, &c. Of these, *Chlamydotherium* attained a size equal to that of the existing Rhinoceroses.

Lastly, the South American Ant-eaters (*Myrmecophagidæ*) are represented in the cave-deposits of Brazil by the extinct *Glossotherium*.

CHAPTER XLI.

ORDERS OF MAMMALIA (Continued).

Sirenia and Cetacea.

Order IV. Sirenia.—This order comprises no other living animals except the Dugongs and Manatees, which are often placed with the true *Cetaceans* (Whales and Dolphins) in a common order. There is no doubt, in fact, but that the *Sirenia* are very closely allied to the *Cetacea*, and though they are to be regarded as separate orders, yet they may be advantageously considered as belonging to a single section, which has been called *Mutilata*, from the constant absence of the hind-limbs.

The *Sirenia* agree with the Whales and Dolphins in their complete adaptation to an aquatic mode of life (fig. 616);

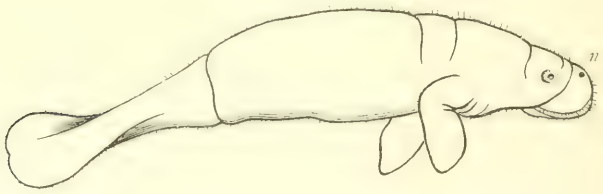


Fig. 616.—Side-view of young *Manatus Americanus*, greatly reduced in size; *n*, Nostrils. (After Murie.)

especially in *the presence of a powerful caudal fin, which differs from that of Fishes in being placed horizontally and in being a mere expansion of the integuments, not supported by*

bony rays. The hind-limbs are wholly wanting,[1] *and there is no sacrum. The anterior limbs are converted into swimming-paddles or "flippers." The snout is fleshy and well-developed, and the nostrils are placed on its upper surface, and not on the top of the head, as in the Whales.* Fleshy lips are present, and the upper one usually carries a moustache. *The skin is covered with scattered bristles.* The head is not disproportionately large, as in the true Whales, and is not so gradually prolonged into the body as it is in the latter. There may be only six cervical vertebræ. There are no clavicles, and the digits have no more than three phalanges each. *The animal is diphyodont (Manatus) or monophyodont (Halicore); the permanent teeth consisting of molars with flattened crowns adapted for bruising vegetable food, and incisors which are present in the young animal, at any rate.* In the extinct *Rhytina* it does not appear that there were any incisor teeth.

The only existing *Sirenia* are the Manatees (*Manatus*) and

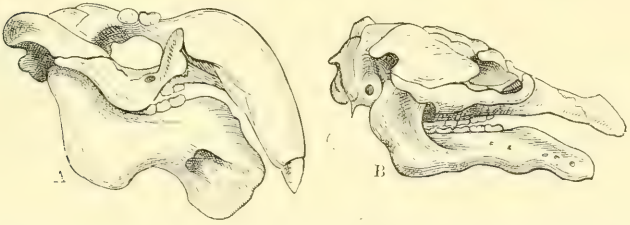


Fig. 617.—A, Side-view of the skull of the Dugong (*Halicore*), showing the tusk-like upper incisors; B, Side-view of the skull of Manatee (*Manatus*). (After Cuvier.)

the Dugongs (*Halicore*), often spoken of collectively as "sea-cows," and forming the family of the *Manatidæ*.

The Manatees (fig. 617) are characterised by the possession of numerous molar teeth, and of two small upper incisors, which are wanting in the adult animal. They are large animals, ten feet or more in length when fully grown, and they live in shallow water near the coast, or ascend rivers for considerable distances, their food being principally aquatic plants.

[1] All the *Sirenia* possess a rudimentary pelvis, and in the extinct *Halitherium* a small femur is present in addition.

The Dugongs (*Halicore*, fig. 617, A) have $\frac{5—5}{5—5}$ or $\frac{6—6}{6—6}$ molar teeth in the young condition, but these are never all in use at one time. The molars are without enamel, and are single-rooted. Inferior incisors are present in the young animal, but are wanting in the adult. The upper jaw carries two permanent incisors, which are entirely concealed in the jaw in the females, but which increase in size in the males with the age of the animal, till they become pointed tusks. The Dugongs are very similar in appearance and habits to the Manatees, but they are more exclusively marine animals, and feed chiefly upon sea-weeds.

The genus *Rhytina*, at one time abundant on the north-west coast of North America, appears to have been completely exterminated about the middle of the eighteenth century. In this curious type there were no true teeth, but the place of the molars was taken by large lamelliform fibrous structures, one on each side of each jaw.

As regards their *distribution in time*, the earliest known remains of this order appear in the Eocene Tertiary of Egypt, where we find the *Eotherium Egyptiacum*, apparently allied to the living Manatees. Of the same age, perhaps, is the interesting form described by Owen from the Tertiary of Jamaica under the name of *Prorastomus sirenoides*. This type is remarkable as possessing upper and lower canines in addition to incisor and molar teeth, the dental formula being—

$$i\ \frac{3—3}{3—3(?)};\quad c\ \frac{1—1}{1—1};\quad pm\ \frac{5—5}{5—5};\quad m\ \frac{3—3}{3—3} = 48.$$

The molars are enamelled, and the incisors are small; the genus thus appearing to be allied to the Manatees, though of a more generalised type.

In the Miocene period Sirenians appear to have been comparatively abundant, though mostly referable to extinct types. In deposits of this age in America, however, occur remains which have been referred to the existing genus *Manatus*. The most important Miocene genus, extending its range into the Pliocene, is *Halitherium* (fig. 618), the skeleton of which is now tolerably well known. In this

genus the general conformation of the skeleton is like that of *Manatus*, though with some points of relationship to the Dugongs. One of the most remarkable features in the skeleton is the presence of a rudimentary femur, no other

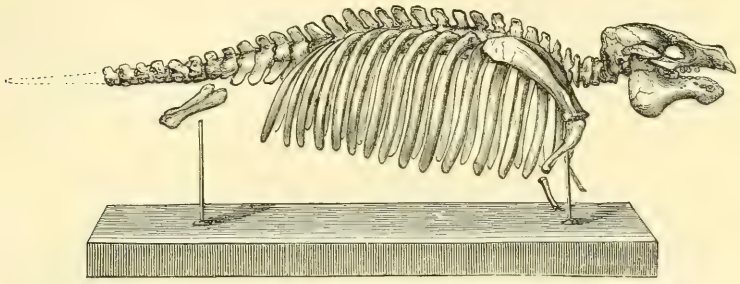


Fig. 618.—Mounted skeleton of *Halitherium* in the Heidelberg University Museum. (After Murie.)

bones belonging to the hind-limb having been hitherto discovered. As regards the dentition, there are tusk-like upper incisors (as in *Halicore*), combined with enamelled molars (as in *Manatus*). The molars are five or six in number on each side of each jaw, and the anterior ones seem to have had vertical successors. The posterior molars are two- or three-rooted, with complex crowns, the pattern of which reminds one of the corresponding teeth in *Hippopotamus* (fig. 619).

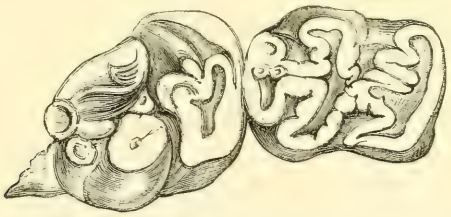


Fig. 619.—Two of the lower molars of *Halitherium Cuvieri*, viewed from above. Miocene Tertiary. (After Blainville.)

The genus *Felsinotherium* of the Tertiary of the South of Europe is closely allied to *Halitherium*, and has five molars on each side of each jaw. *Crassitherium*, from the Pliocene of Belgium, is so called from the thick walls of its skull, and is supposed to be allied to *Rhytina*. Lastly, the remains of

the recently exterminated *Rhytina* occur in the Post-Pliocene of Siberia.

The genus *Deinotherium* referred to this order by De Blainville, and still retained in this position by Pictet, will be here considered as belonging to the order of the *Proboscidea*.

Order V. Cetacea.—In this order are the Whales, Dolphins, and Porpoises, all agreeing with the preceding in their complete adaptation to an aquatic life. *The body is completely fish-like in form; the anterior limbs are converted into swimming-paddles or "flippers;" the proximal bones of the fore-limbs are much reduced in length, and the succeeding bones are shortened and flattened, and are enveloped in a tendinous skin, thus reducing the limbs to oar-like fins; there are no external ears; the posterior limbs are completely absent; and there is a powerful, horizontally-flattened caudal fin, sometimes accompanied by a dorsal fin as well.* In all these characters the *Cetacea* agree with the *Sirenia*, except in the one last mentioned. On the other hand, *the nostrils, which may be single or double, are always placed at the top of the head, constituting the so-called "blow-holes" or "spiracles;" and they are never situated at the end of a snout. The body is very sparingly furnished with hairs, or the adult may be completely hairless. The head is generally of disproportionately large size, and is never separated from the body by any distinct constriction or neck.* The lumbar region of the spine is long, and, as in the *Sirenia*, there is no sacrum, and the pelvis is represented by a single bone (the ischium) on each side. A rudimentary femur may be present, and *Balæna mysticetus* has a cartilaginous tibia as well. There are no clavicles, and some of the digits may possess more than three phalanges each. Lastly, *the adult is either destitute of teeth, or, with the single exception of the Zeuglodontidæ, is monophyodont*—that is to say, possesses but a single set of teeth, which are never replaced by others. *When teeth are present, they are usually conical and numerous, and, except in the Zeuglodonts, they are always of one kind only.*

The *Cetacea* may be divided into the five families of the *Balænidæ* or Whalebone Whales, the *Delphinidæ* or Dolphins and Porpoises, the *Catodontidæ* or Sperm Whales,

the *Rhynchoccti* or Ziphioid Whales, and the *Zeuglodontidæ*. Of these, the *Balænidæ* are often spoken of as the "toothless" Whales, whilst the other four families are called the "toothed" Whales (*Odontoceti*).

Fam. 1. *Balænidæ*.—The *Balænidæ* or Toothless Whales are characterised by the total absence of teeth in the adult (fig. 620). Teeth, however, are present in the fœtal Whale,

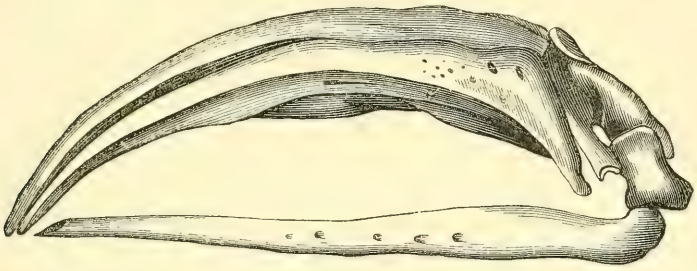


Fig. 620.—Skull of the Right Whale (*Balæna mysticetus*). (After Owen.)

but they never cut the gum. The place of teeth is supplied by a number of plates of whalebone or "baleen" attached to the palate; hence the name of "Whalebone Whales" often given to this family. They are the largest of living animals, and may be divided into the two sections of the *Smooth* Whales, in which the skin is smooth, and there is no dorsal fin (as in the Greenland Whale), and the *Furrowed* Whales, in which the skin is furrowed, and a dorsal fin is present (as in the so-called Finner Whales and Hump-backed Whales).

So far as at present known, the importance of the *Balænidæ*, from a palæontological point of view, is not great. It is very doubtful if any member of this group has been found in any Secondary deposit. The only exception to this statement—and it is a doubtful one—is that of the cervical vertebræ of *Palæocetus*, which were discovered in glacial accumulations near Ely, and are supposed to have been washed out of the Kimmeridge Clay (Jurassic). These are believed to belong to a Whalebone Whale. In the Miocene and Pliocene Tertiary we meet for the first time with undoubted remains of *Balænidæ*. Of this nature are the extinct *Hoplocetus* of the Pliocene, and the *Cetotherium* and *Cetotheriopsis* of the

"Sarmatian" deposits, all of which appear to be more or less closely related to the living Finner Whales (*Balænoptera*). The living genus *Balæna* appears for the first time in the Pliocene of Europe; and it is probable that the ear-bones or "cetotolites," which occur in the Red Crag (Pliocene), are, in some instances at any rate, referable to members of the *Balænidæ*.

Fam. 2. *Catodontidæ*.—The family of the *Catodontidæ*, or *Physeteridæ*, comprises the Sperm Whales or Cachalots, with which we commence the series of the Toothed Whales (*Odontoceti*). They are characterised by the fact that the palate is destitute of baleen-plates, and the lower jaw possesses a series (about fifty-four) of pointed conical teeth, separated by intervals, and sunk in a common alveolar groove, which is only imperfectly divided by septa. The upper jaw is also in reality furnished with teeth—but, with a single partial exception, these do not cut the gum.

Remains of Cachalots (*Physeter*) occur in the Pliocene and Post-Tertiary deposits, and their existence has even been indicated in the Miocene Tertiary. They are, however, of no special importance.

Fam. 3. *Delphinidæ*.—This family includes the Dolphins, Porpoises, and Narwhal, and is characterised by usually possessing teeth in both jaws; the teeth being numerous, and conical in shape. The nostrils, as in the last family, are united, but they are placed further back, upon the top of the head. The single blow-hole or nostril is transverse, and mostly crescentic or lunate in shape. The head is by no means so disproportionately large as in the former families, usually forming about one-seventh of the entire length of the body.

The genus *Delphinus*, comprising the common Dolphins, appears to date from the Miocene Tertiary, and is well represented in deposits of Pliocene age. In Miocene strata also occur the Delphinoid remains which have been referred to the genera *Priscodelphinus*, *Stereodelphis*, and *Champsodelphis*.

Fam. 4. *Rhynchoceti*.—This family is allied to that of the Cachalots or Sperm Whales, and includes the so-called "Ziphioid Whales." They are distinguished by the posses-

sion of a pointed snout (the "beak" or "rostrum"), single blow-hole, and small dorsal fin; and by their dentition. The upper jaw is edentulous, any teeth which may be present not cutting the gum. The lower jaw, on the other hand, possesses usually a single pair of teeth, which are sometimes tusk-like, but which in other cases are concealed by the gum.

The rostrum of these Cetaceans is of great density, and has often been preserved in a fossil state, usually presenting itself as a bony cylinder or elongated cone, generally more or less water-worn. Upon fossils of this nature have been

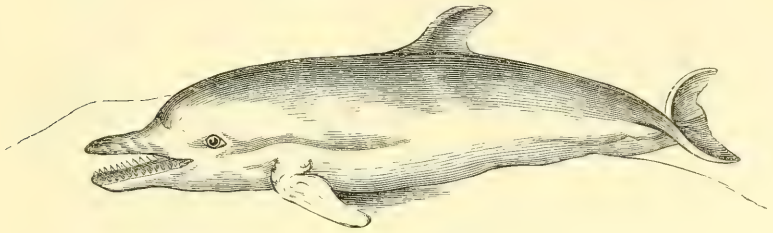


Fig. 621.—The common Dolphin (*Delphinus delphis*).

founded the genera *Choneziphius* and *Belemnoziphius*, both of which occur in the so-called "Crags" (Pliocene). The genus *Ziphius* also occurs in the Crag, but unlike the preceding it is represented by existing species. Besides the "beaks," some fossil teeth have been found, which may perhaps be referable to members of this family.

Fam. 5. *Zeuglodontidæ.* — The members of this family differ from all existing *Odontoceti* in the possession of molar teeth implanted by two distinct fangs. Incisor teeth are likewise present, and the animal is diphyodont. The Zeuglodonts are entirely extinct, and they are exclusively confined to the Eocene, Miocene, and Pliocene periods. The chief genera are *Zeuglodon* and *Squalodon*.

Zeuglodon (fig. 622) is distinguished by its elongated snout, conical incisors, and molar teeth with triangular serrated crowns, implanted in the jaw by two roots. Each molar looks as if it were composed of two separate teeth united on one side by their crowns; and it is this peculiarity

which is expressed by the generic name. The species of *Zeuglodon* are Eocene and Miocene, one of the best known being the great *Z. cetoides* of the Middle Eocene (Jackson Beds) of the United States, which attained a length of seventy feet.

By Professor Huxley, *Zeuglodon* is regarded as in some respects intermediate between the true Cetaceans and the

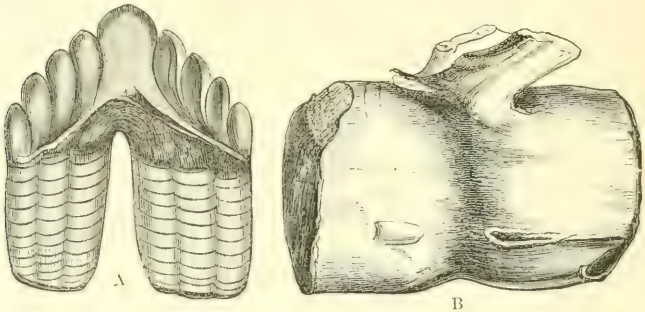


Fig. 622.—*Zeuglodon cetoides*. A, Molar tooth, natural size; B, Vertebra, reduced. From the Middle Eocene of North America. (After Lyell.)

Carnivorous family of the Seals. On this point this eminent naturalist remarks: "The skull of this great Eocene sea-monster, in fact, shows, by the narrow and prolonged inter-orbital region; the extensive union of the parietal bones in a sagittal suture; the well-developed nasal bones; the distinct and large incisors implanted in præmaxillary bones, which take a full share in bounding the forepart of the gape; the two-fanged molar teeth with triangular and serrated crowns, not exceeding five on each side in each jaw; and the existence of a deciduous dentition,—its close relation with the Seals. While, on the other hand, the produced rostral form of the snout, the long symphysis, and the low coronary process of the mandible, are approximations to the Cetacean form of those parts."

The genus *Squalodon* is nearly related to *Zeuglodon*, but the teeth are more numerous; and the double-fanged molars (fig. 623) are more compressed and pyramidal in form. "The nasal bones are very short, and the upper surface of the rostrum presents the groove, filled up during life by the

prolongation of the ethmoidal cartilage, which is so characteristic of the majority of Cetaceans" (Huxley). The species of *Squalodon* all belong to the Miocene and Pliocene Tertiary.

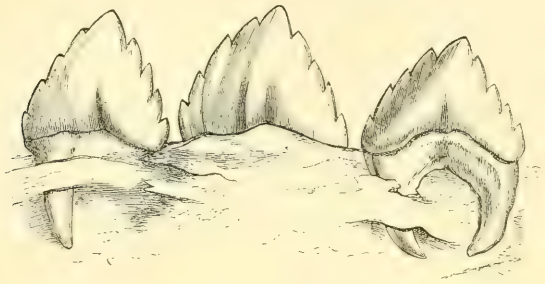


Fig. 623.—Three of the lower molars of *Squalodon*. Miocene Tertiary. (After Scilla.)

The genus *Saurocetes* has been founded for the reception of another Zeuglodont, in which there were double-fanged teeth with conoid crowns. The remains on which this genus are based are from strata of Tertiary age, near Buenos Ayres, and they indicate an animal much smaller than the true *Zeuglodons*.

Lastly, it would appear probable that the genus *Balænodon*, founded upon teeth from the Red Crag (Pliocene), is really referable to this family, and probably to the genus *Squalodon*. In part, however, teeth of Ziphioid Whales have also been included under this title. By Owen, *Balænodon* is regarded as comprising teeth of a Cetacean nearly allied to the living Sperm Whale.

CHAPTER XLII.

ORDERS OF MAMMALIA (Continued).

Ungulata.

Order VI. Ungulata.—The order of the *Ungulata*, or Hoofed Quadrupeds, is one of the largest and most important of all the divisions of the *Mammalia*. It comprises three entire old orders—namely, the *Pachydermata*, *Solidungula*, and *Ruminantia*.

The first of these old divisions—that of the *Pachydermata*—included the Elephants, Rhinoceros, Hippopotamus, Tapirs, and the Pigs, all characterised, as the name implies, by their thick integuments. The name is still used to express this fact, though the order is now abandoned, and is merged with that of the *Ungulata*; the Elephants alone being removed to a separate order under the name of *Proboscidea*.

The second old order—that of the *Solidungula* or Solipedes—included the Horse, Zebra, and Ass, all characterised by the fact that the foot terminates in a single toe, encased in an expanded hoof. The name *Solidungula* is still retained for these animals, as a section of the *Ungulata*.

The third old order—that of the *Ruminantia*—includes all those animals, such as Oxen, Sheep, Goats, Camels, Giraffes, Deer, and others, which chew the cud or "ruminate," and have two functional toes to each foot, encased in hoofs. The name *Ruminantia* is still retained for these animals, as constituting a most natural group of the *Ungulata*.

All these various animals, then, are now grouped together

into the single order of the *Ungulata*, or Hoofed Quadrupeds, and the following are the characters of the order:—

All the four limbs are present, and that portion of the toe which touches the ground is always encased in a greatly-expanded nail, constituting a "hoof." There are rarely more than four full-sized toes to each limb. Owing to the encasement of the toes in hoofs, the limbs are useless for prehension, and only subserve locomotion; hence clavicles are always wanting in the entire order. There are always two sets of enamelled teeth, so that the animal is diphyodont. The molar teeth are massive and have broad crowns, adapted for grinding vegetable substances.

The order *Ungulata* is divided into two primary sections: the *Perissodactyla*, in which the toes or hoofs are odd in number (one or three, or rarely five), and the *Artiodactyla*, in which the toes are even in number (two or four).

Both these great sections were differentiated as early as the Eocene Tertiary, in which formation are found the oldest remains of Ungulates which have been as yet discovered. The ancestral types from which these sections were derived are still unknown to us, but it is to be expected that these will be found to possess the full five digits which are normally present in the mammalian limb. It might, therefore, be not unadvisable to create a third section of the *Ungulata*, which might be termed *Teleodactyla*, for the reception of those forms in which the foot is five-toed. In the meanwhile, however, the few known pentadactylous Ungulates (the *Coryphodontia*) may be temporarily retained in the Perissodactyle section of the order, with which they have affinities in other respects.

Section A. Perissodactyla.

The section of the *Perissodactyle* Ungulates includes the living types of the Rhinoceroses, Tapirs, and Horses, together with a vast number of extinct forms, only the more important of which can be alluded to here. The characters of the section are as follows:—

The hind-feet are odd-toed in all (fig. 624, B), *and the fore-*

feet in all except the Tapirs and Brontotheridæ. The dorso-lumbar vertebræ are never less than twenty-two in number. The femur has a third trochanter. The horns, if present, are not paired (except in the extinct genus Diceratherium). Usually there is only one horn, but if there are two, these are placed in the middle line of the head, one behind the other. In neither case are the horns ever supported by bony horn-cores. The stomach is simple, and is not divided into several compartments; and there is a large and capacious cæcum.

The typical state of matters in the Perissodactyles is that the third digit of the foot should be pre-eminently and symmetrically developed, and should either exist alone (*Equus*), or should be flanked by the second and fourth digits, the

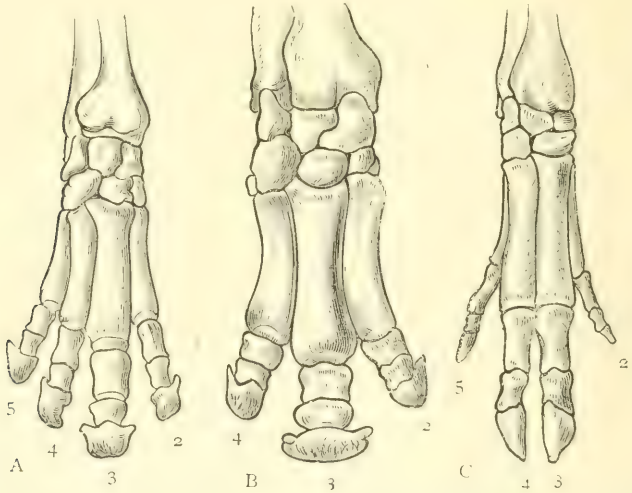


Fig. 624.—Feet of Ungulata. A, Fore-foot of Tapir (*Tapirus Malayanus*); B, Perissodactyle fore-foot of *Rhinoceros Sumatrensis*; C, Artiodactyle foot of Pig (*Sus scrofa*). The figures indicate which of the normal five digits are present in each foot. (After Flower.)

size and length of these varying in different cases, but always falling short of the dimensions of the central digit (*Rhinoceros*, fig. 624, B). No living *Perissodactyle* Ungulate possesses the inner or first digit on either fore or hind feet. The Tapirs, however, have a small fifth digit (fig. 624, A) developed on the fore-feet, the inner digit of which is still wanting; the extinct *Orohippus* has similarly the fifth digit developed

in the fore-foot; and in the extinct *Eohippus* there is even a rudimentary first digit or pollex. Lastly, in the extinct Coryphodonts, which, as before said, might with some advantage be placed in a separate section (*Teleodactyla*), the feet are furnished with the full complement of five digits on all the feet, and all of these are sufficiently developed to touch the ground. Provisionally admitting these ancient five-toed types into the *Perissodactyla*, we may divide this section of Ungulates into the seven principal families of the *Coryphodontidæ*, *Rhinoceridæ*, *Tapiridæ*, *Brontotheridæ*, *Palæotheridæ*, *Macrauchenidæ*, and *Equidæ*. Of these, the families of the *Rhinoceridæ*, *Tapiridæ*, and *Equidæ* alone survive; and widely separated as they are in many important characters, the intervals between them are to a large extent filled up by an extensive series of fossil forms.

Fam. 1. *Coryphodontidæ*.—In this family is comprised the genus *Coryphodon* only, this being apparently identical with the *Bathmodon* of Cope. First founded by Owen upon fragmentary remains discovered in the Eocene Tertiary of Britain, the characters of the genus have now been largely elucidated by Professor Marsh from the much more ample material obtained from strata of the same age in North America. The genus *Coryphodon* comprises large Tapir-like animals, all belonging to the period of the Eocene Tertiary, and having an average size about equal to that of the living Tapirs. The skull (fig. 625, A) is of the Perissodactyle type, and is hornless, the comparatively small size of the nasal bones indicating that the nose was not prolonged into a proboscis. The brain is remarkably small, and of an altogether inferior type of organisation—casts of the brain-case indicating that the cerebellum was large, the cerebral hemispheres much reduced in size, and "the olfactory lobes large and entirely in advance of the hemispheres" (Marsh). The dentition is complete, the dental formula being—

$$i\,\frac{3—3}{3—3};\ c\,\frac{1—1}{1—1};\ pm\,\frac{4—4}{4—4};\ m\,\frac{3—3}{3—3} = 44.$$

The canines are not excessively developed, and the molars are of the Tapiroid type, and have two transverse crests or

ridges. The limbs are short; the femur has a third trochanter; and the feet are furnished with five digits each (fig. 625, B and C), all of these being functionally complete.

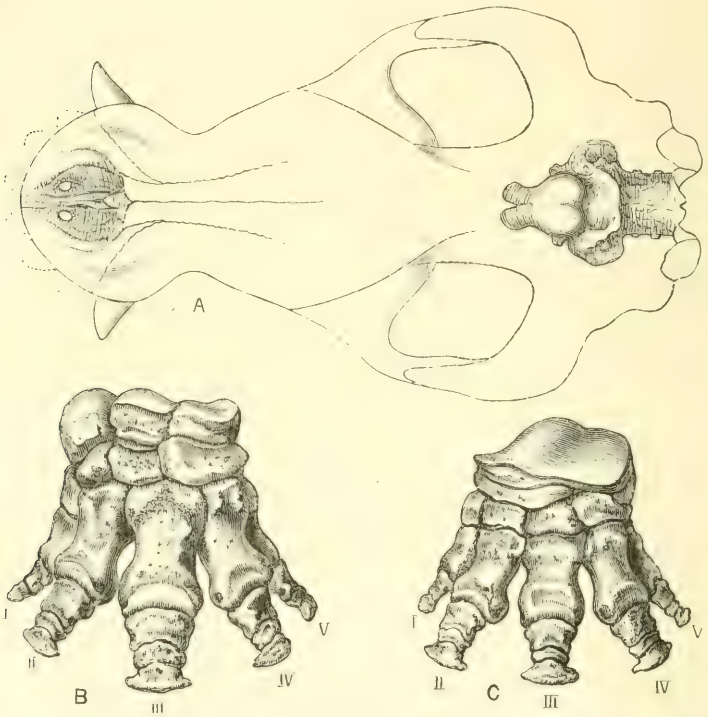


Fig. 625.—A, Outline of skull and brain-cavity of *Coryphodon hamatus*, viewed from above, one-fifth of the natural size; B, Fore-foot of *Coryphodon*, one-third of the natural size; C, Hind-foot of *Coryphodon*, one-third of the natural size. Lower Eocene, North America. (After Marsh.)

Fam. 2. *Rhinocerida.*—This family comprises only a single living genus, the genus *Rhinoceros*, unless, indeed, the little *Hyrax* is to be placed here. The Rhinoceroses are extremely large and bulky brutes, having a very thick skin, which is usually thrown into deep folds. The muzzle is rounded and blunt, and there are $\frac{7-7}{7-7}$ molars, with tuberculate crowns. There are no canines, but there are usually incisor teeth in both jaws. The skull is pyramidal, and the nasal bones are generally enormously developed. The feet (fig. 624, B) are

furnished with three toes each, encased in hoofs. The nasal bones usually support one or two horns, composed of longitudinal fibres, which are agglutinated together, and are of the nature of epidermic growths, somewhat analogous to hairs. The Rhinoceroses live in marshy places, and subsist chiefly

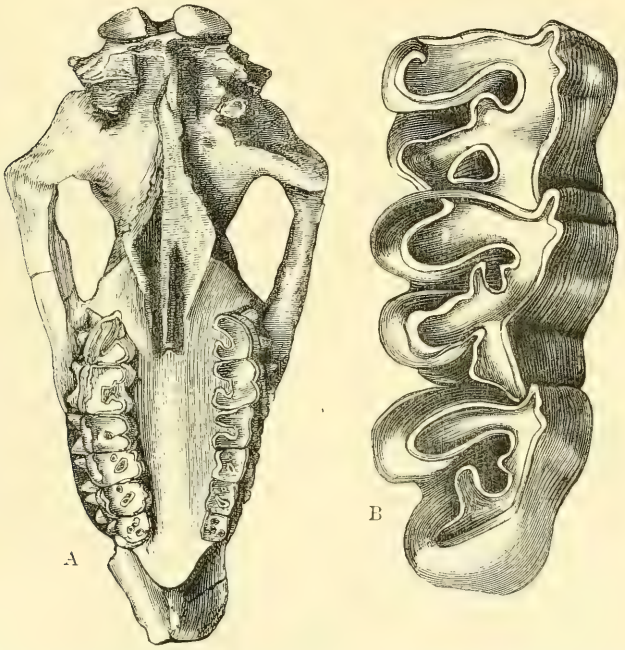


Fig. 626.—A, Under surface of the skull of *Rhinoceros Etruscus*, one-seventh of the natural size—Pliocene, Italy; B, Crowns of the three true molars of the upper jaw, left side, of *Rhinoceros megarhinus* (*R. leptorhinus*, Falconer), one-half the natural size—Pliocene, France. (After Falconer.)

on the foliage of trees. They are exclusively confined at the present day to the warmer parts of the Old World; but an extinct species (*Rhinoceros tichorhinus*) formerly inhabited England, and ranged over the greater part of Europe.

The genus *Rhinoceros* appears for the first time in the Miocene Tertiary, and still survives; while it is represented in the earlier period of the Eocene by allied genera. Throughout its long range the genus exhibits a considerable amount of variability, and even the now existing species differ from

one another in points of considerable importance, some of which may be briefly alluded to.

In the first place, as regards the dentition considerable differences obtain among different species of the genus. The typical dental formula is—

$$i\ \frac{1—1}{1—1}\ \text{or}\ \frac{0—0}{0—0}\ ;\ c\ \frac{0—0}{0—0};\ pm\ \frac{4—4}{4—4}\ ;\ m\ \frac{3—3}{3—3}$$

In many species, such as the living two-horned Rhinoceroses of Africa, there are no incisor teeth at all in the fully-grown animal. In other cases (*e. g.*, in the living *R. Indicus*) there are two incisors in the front of both the upper and the lower jaw, and the lower incisors are longer and more pointed than the upper. In some of the Miocene Rhinoceroses (such as *R. Schleiermacheri*) the front of the lower jaw carries four teeth, of which the two central ones are small, while the outer ones are long and pointed. These tusk-like teeth are generally regarded as an external pair of incisors, but they are looked upon by Gervais and Gaudry as being truly canines. In the hornless Miocene Rhinoceroses, which constitute the genus *Acerotherium*, the condition of matters is usually as just mentioned. That is to say, the lower jaw carries a pair of minute central incisors and a pair of tusk-like lateral incisors (canines?); but the former may be wanting, and in one species of the genus the front of the lower jaw carries a series of eight teeth, six incisors and two canines. Lastly, the *Rhinoceros Sivalensis* of the Siwâlik Hills is stated by Falconer to possess six lower incisors.

On each side of both lower and upper jaws there exists in the Rhinoceroses a continuous series of seven grinding teeth, of which the first four are præmolars, and the hinder three are molars (fig. 626 A). The crowns of these (fig. 626 B, and figs. 627 and 628) are of the Palæotherian type, there being two principal transverse tracts of dentine, separated by an anterior and posterior valley, not filled up with cement.

Another point in which the Rhinoceroses differ remarkably from one another is in the form and development of the nasal bones, these differences being due to the absence

or presence of horns and the variable development of these appendages when present. In the Miocene period we meet with various species of Rhinoceroses which are entirely

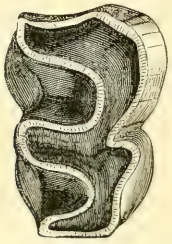


Fig. 627.—Penultimate molar of the lower jaw of *Rhinoceros megarhinus*, two-thirds of the natural size. Post-Pliocene.

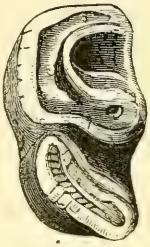


Fig. 628.—Penultimate molar of the lower jaw of *Rhinoceros tichorhinus*, two-thirds of the natural size. Post-Pliocene.

devoid of horns, and which are grouped together under the generic or sub-generic title of *Acerotherium*. In these forms (fig. 629) the nasal bones are very greatly reduced in size, though they vary in their dimensions in different species.

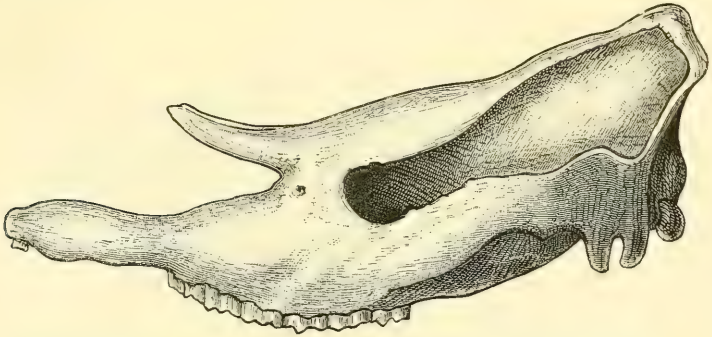


Fig. 629.—Skull of *Acerotherium* (*Rhinoceros*) *incisivum*, one-seventh of the natural size. Miocene Tertiary. (After Kaup.)

It may be added here, that in addition to the absence of horns the species of *Acerotherium* are distinguished by the low crowns of the præmolar and molar teeth, the general presence of two or more lower incisors additional to the single pair normally present, and the fact that the fore-feet are typically or always four-toed (as in the living Tapirs).

There is thus good reason for separating *Aceratherium* generically from *Rhinoceros*.

The typical Rhinoceroses all possess immensely-developed nasal bones, to serve for the support of a horn or horns, this purpose being occasionally further subserved by the partial or complete ossification of the septum between the nostrils. We may therefore divide the species of Rhinoceros, in accordance with this character, into three groups:—

1. Those in which the nasal septum remains unossified (*Rhinoceros megarhinus*).

2. Those in which the nasal bones are strengthened by the partial ossification of the nasal septum, giving rise to an incomplete bony partition or "cloison" between the nostrils (*R. Etruscus* and *R. hemitœchus*).

3. Those in which the nasal septum is completely ossified, and the nostrils are thus separated by an unbroken partition or "cloison." This condition is coincident with the great development of the horns, and is especially well seen in the Woolly Rhinoceros (*R. tichorhinus*, fig. 630).

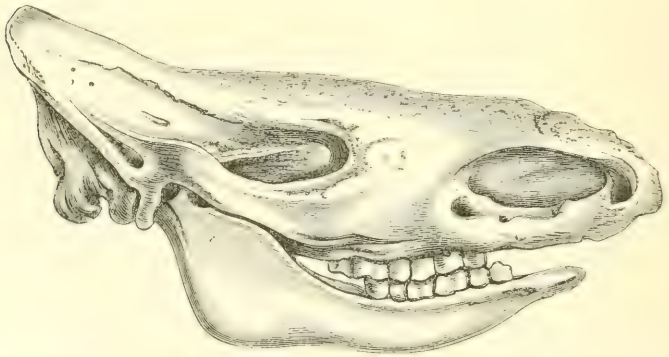


Fig. 630.—Skull of the Tichorhine Rhinoceros, the horns being wanting. One-tenth of the natural size. Post-Pliocene deposits of Europe and Asia.

The horns of the Rhinoceroses are, as has been mentioned, epidermic structures, and are totally distinct in their nature from the horns of the Hollow-horned Ruminants or of the Deer. In the so-called "unicorn" Rhinoceroses there exists but a single horn placed upon the nasal bones in the median line of the head. In the "bicorn" Rhinoceroses, on the

other hand, there are two of these appendages, also placed upon the nasal bones in the median line of the head, the posterior horn being shorter than the anterior, or differing from it in form. While the true Rhinoceroses have invariably a *median* horn or horns, we shall see shortly that there existed allied types (viz., *Colonoceras* and *Diceratherium*) in which the horns were *paired*.

Even excluding *Acerotherium*, we find true forms of *Rhinoceros* in existence as early as the Miocene period (*R. Schleiermacheri*, *R. pachygnathus*, &c.); and there are numerous fossil species in the Pliocene and Post-Pliocene deposits of the Old World. In the New World the genus *Rhinoceros* itself does not appear to be represented, but the Miocene and Pliocene deposits of North America have yielded several species of *Acerotherium*. Of the fossil forms of *Rhinoceros*, the most important are *R. tichorhinus*, *R. megarhinus*, *R. hemitœchus*, and *R. Etruscus*.

The *Rhinoceros tichorhinus* (fig. 630) is generally known as the "Woolly Rhinoceros," from its possession of a woolly covering. Its skin was foldless, and it possessed two horns, of which the anterior one was very large. The limbs are extremely stout, and the nostrils are completely separated by an osseous septum. *R. tichorhinus* is essentially a northern form, and has the same distribution *in space* as the Mammoth, except that it did not cross Behring's Straits, and is therefore not found in America. In *time*, it is younger than the Mammoth, not being found in the præ-glacial forest-bed of Norfolk, and occurring for the first time in the Lower Brick-earths of the Thames valley (præ-glacial, but younger than the "forest-bed"). It is therefore essentially a Post-glacial Mammal, and it is mainly found in quaternary cave-deposits and valley-gravels.

The *Rhinoceros hemitœchus* of Falconer (= the *R. leptorhinus* of Owen) is also provided with two horns, but is of a much more slender build than the Tichorhine form. The nasal bones are slender, and the nostrils are separated by a partially-ossified septum. The adult animal possesses neither incisor nor canine teeth. Like the preceding, *R. hemitœchus* is exclusively Post-Pliocene in its distribution,

and is found in cave-deposits and in the Thames valley Brick-earths.

The *Rhinoceros megarhinus* of Christol (=the *R. leptorhinus* of Cuvier and Falconer) is also bicorn, and resembles *R. hemitæchus* in being of comparatively slender build. It is distinguished, however, by the enormous development of the nasal bones and the absence of the "cloison" or bony partition between the nostrils. This form (fig. 627) is found in the Pliocene beds of Italy and France, and also occurs in the præ-glacial forest-bed of Cromer and the Lower Brick-earths of the Thames valley.

Rhinoceros Etruscus (fig. 626, A) is also bicorn, and has the nostrils partially separated by a "demi-cloison" or incomplete bony partition, which "strengthened the basement of the anterior horn." This species is found in deposits of Pliocene age, and occurs also in the Post-Pliocene (as in the Cromer forest-bed).

In addition to *Rhinoceros* and *Acerotherium*, the Tertiary rocks have yielded various other forms of *Rhinocerida*, some of which depart very widely from the general type. The oldest known forms are *Amynodon* and *Colonoceras*, both of which are found in the Eocene Tertiary of North America. In *Amynodon* there were no horns, and there were both upper and lower canines, while none of the præmolars were like the molars. *Colonoceras*, again, is very closely allied to the Tapiroid genus *Hyrachyus*, but it has the curious character that the nasal bones carried two very rudimentary osseous protuberances for the support of a pair of minute horns; these appendages, however, being placed symmetrically on the sides of the head, instead of being situated one behind each other in the middle line. The possession of symmetrically-placed *transverse* horns is, however, a more conspicuous feature in the Miocene genus *Diceratherium*, which nearly equalled the existing Rhinoceroses in point of size, and closely resembled them in other structural characters, except that the fore-feet are four-toed. The genus is North American, as is also the curious *Hyracodon* of the Miocene, in which horns were completely wanting, and in which there is the

generalised feature that the dentition was complete, there being six incisors and two canines in each jaw.

In the later Tertiary deposits of Patagonia have been found the remains of another generalised type, which may perhaps be placed here, and which has been described under the name of *Homalodontotherium*. In this form there is the complete dentition of forty-four teeth, placed in a continuous series, and of nearly equal height. The molars are like those of *Rhinoceros*, to which the genus may be supposed to be allied through *Hyracodon*.

Lastly, we may mention here the singular *Elasmotherium* of the Post-Pliocene of northern, central, and southern Europe, which was allied to the *Rhinoceros*, but with various quite peculiar characters. The body was of very large size, the length probably not falling short of fourteen or fifteen feet, and the skull seems to have carried two mesially-placed horns, of which the posterior one was much the largest. The nasal septum is ossified, as in various species of *Rhinoceros*. The limbs, however, are unknown; and the molars are not at all of the Rhinoceroid pattern, but, on the contrary, were complicated by elaborately-folded plates of enamel.

Fam. 3. *Tapiridæ*.—The Tapirs (*Tapirus*) are characterised by the possession of a short movable proboscis or trunk. The skull (fig. 631) is pyramidal, like that of the pigs, and

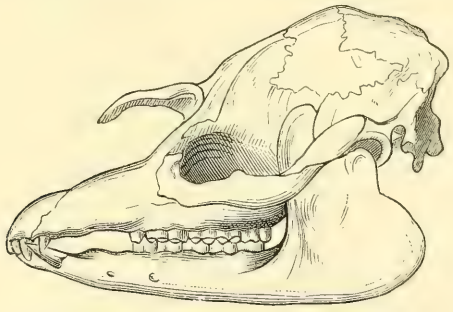


Fig. 631.—Side view of the skull of the living *Tapirus Americanus*. (After Giebel.)

the nasal bones project over the nasal cavity. The skin is hairy and thick. The tail is extremely short. The fore-

feet (fig. 624, A) have *four* toes each, but these are unsymmetrical (the little toe being smaller than the rest, and not touching the ground), and the hind-feet have only three toes, all encased in hoofs. The dental formula is—

$$i\,\frac{3—3}{3—3};\ c\,\frac{1—1}{1—1};\ pm\,\frac{4—4}{3—3};\ m\,\frac{3—3}{3—3}=42.$$

The canines do not form projecting tusks, and the molars and præmolars are of the "bilophodont" type, the crown of each presenting two transverse or oblique ridges, separated by broad and shallow valleys. The living species of *Tapirus* are found in South America, the Malayan Archipelago, and China; and the genus appears to make its first appearance in the Miocene Tertiary, where it is represented by forms like the *T. Poirrieri* and *T. priscus* of Europe. In the European Pliocene we have the well-known *T. Arvernensis;* and in the Post-Pliocene of North America the genus is widely distributed.

At the present day the genus *Tapirus* is the sole surviving member of the *Tapiridæ,* but we have an extensive series of Tertiary genera, commencing as early as the Eocene. One of the most important of these is the genus *Lophiodon,* of the Eocene of Europe, which appears to have closely resembled the Tapirs in most respects, but to have possessed some peculiar dental characters. The molars are of the "bilophodont" type (fig. 632, A), each exhibiting two oblique ridges, separated by anterior and posterior valleys or sinuses; and the præmolars have the same general character, but want the posterior ridge. The molars are thus of essentially the same type as those of *Tapirus,* but there is now one præmolar less on each side of the upper jaw, the dental formula being—

$$i\,\frac{3—3}{3—3};\ c\,\frac{1—1}{1—1};\ pm\,\frac{3—3}{3—3};\ m\,\frac{3—3}{3—3}=40.$$

The limbs of *Lophiodon* are still unknown, but such portions of the skeleton as have been discovered are distinctly Tapiroid in character. The genus has not yet been satisfactorily

identified in the New World, but it abounded in Europe during the Eocene period, the species varying from the size of a hare to that of a *Rhinoceros*. Closely allied to one another, or absolutely identical, are the forms which have been described under the names of *Hyracotherium*, *Pachynolophus*, *Pliolophus*, *Lophiotherium*, and *Propalæotherium*. These are Tapiroid genera from the Eocene Tertiary of the European area, in which the transverse ridges of the molars become broken up into transversely-arranged tubercles.

In the Eocene of North America the place of *Lophiodon* and its European allies seems to be taken by *Helaletes* and *Hyrachyus* (fig. 632, B). The latter is strongly Tapiroid in

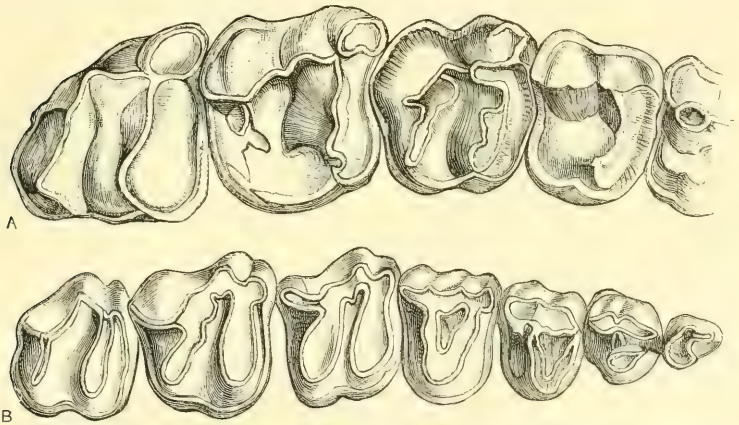


Fig. 632.—A, The three molars and hindmost præmolar of the upper jaw on the right side of *Lophiodon Isselense*, showing the grinding surfaces, Eocene (after Gervais); B, Triturating surfaces of the molars and præmolars of *Hyrachyus agrarius*, Eocene of North America (after Leidy).

its general characters, having four præmolars in the upper jaw on each side (as in *Tapirus*), and either three or four lower præmolars. The præmolars, too, resemble those of *Lophiodon* in being less complex than the molars. In the Miocene of North America few remains of *Tapiridæ* have been discovered, and those that are known appear to belong to the genus *Tapiravus*.

We may also provisionally place here a group of American Eocene Mammals (the *Limnohyidæ* of Professor Marsh), which are in many respects allied to the Tapirs, but are at

the same time so closely related to the *Palæotheridæ*, that, in the present state of our knowledge, they might be included with equal propriety in either family. The chief genus in this group is *Palæosyops*, in which the teeth form an almost continuous series, and the dental formula was—

$$i\ \frac{3-3}{3-3};\ c\ \frac{1-1}{1-1};\ pm\ \frac{4-4}{4-4};\ m\ \frac{3-3}{3-3} = 44.$$

The molars are of the Palæotheroid type; but the canines were very large and pointed, and resembled those of the *Carnivora*. *Limnohyus*, also from the Eocene, differs from the preceding only in the pattern of the molar teeth. The Eocene *Diplacodon*, lastly, resembles the preceding in many points, but, though hornless, shows points of relationship to the *Brontotheridæ*.

Fam. 4. *Brontotheridæ*. — We may provisionally place here the large fossil Mammals from the Miocene of North America, which Professor Marsh has described under the name of *Brontotheridæ*. In these, the fore-feet have four

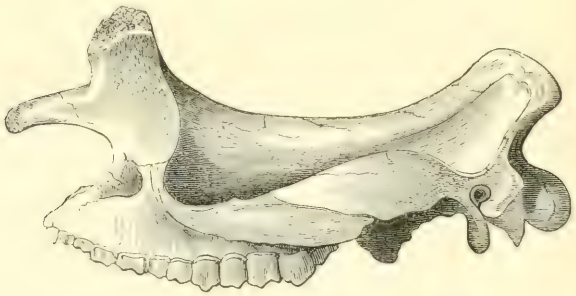


Fig. 633.—Skull of *Brontotherium ingens*. (After Marsh.)

nearly equal toes, and the hind-feet three, thus numerically resembling the feet of the Tapirs, but the third digit of the fore-foot has not the pre-eminent development that it has in the latter. In size and in the conformation of the skeleton, the *Brontotheridæ* resemble the Elephants, but the limbs are much shorter, and the tail seems to have been long; and though the nose was probably long and flexible, there does not appear to have been any true proboscis. The skull

was elongated, and the brain-cavity was very small, the cerebral hemispheres not extending over the cerebellum, and little or not at all over the olfactory lobes. There is a pair of large bony protuberances or horn-cores placed symmetrically and transversely upon the maxillary bones in both sexes. The nasal bones are elongated, and overhang the nasal cavity. The dental formula in *Brontotherium* is—

$$i\,\frac{2—2}{2—2};\quad c\,\frac{1—1}{1—1};\quad pm\,\frac{4—4}{3—3};\quad m\,\frac{3—3}{3—3}=38.$$

The incisors are small; and the canines are short and not separated from the præmolars by any diastema, these latter being much smaller than the molars. The præmolars show two external connate cusps and two closely-united internal cones, and the upper molars have an essentially similar structure, while the lower molars are of the Palæotherian type. The chief genus is *Brontotherium*, with which the *Symborodon* and *Miobasileus* of Professor Cope are more or less entirely synonymous.

The genera *Titanotherium*, *Megacerops*, and *Diconodon* also belong to this group.[1]

Fam. 5. *Palæotheridæ.*—This family comprises a number of remarkable Eocene and Miocene Mammals, which are related closely to both the Tapirs and the *Equidæ*. The type-genus is *Palæotherium* itself, which abounded under various specific forms in the European area during the earlier portion of the Tertiary period. The *Palæotheria* possessed feet very much like those of the Tapirs, but there were only three digits to both fore-feet and hind-feet. The skull is also Tapiroid in its character, especially in the prominence of the nasal bones, from which it is deduced with great probability that the nose possessed a short movable proboscis. The general form also may be supposed to have been like that of the Tapirs, and the restoration of *Palæotherium magnum* given by Cuvier (fig. 634) exhibits

[1] American palæontologists are by no means agreed as to the number of generic types in the *Brontotheridæ*, or even as to the *names* of these. As it is quite impossible for the author to decide this question on its merits, he has adopted the names used by Marsh, who has most fully elucidated the group.

to us an animal closely similar to the existing American Tapir. In this particular instance, however, we know that the restoration is incorrect, since the discovery of a complete specimen of this species has shown that it was a slender, graceful, and long-necked animal, resembling in its general figure a Llama or certain of the Antelopes.

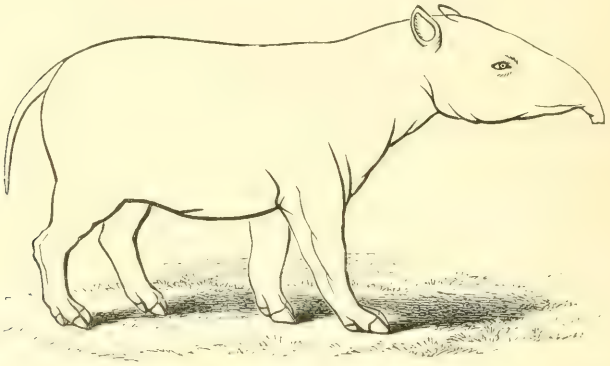


Fig. 634.—Outline of *Palæotherium magnum*, restored, after Cuvier. Upper Eocene.

As regards its dentition, the genus *Palæotherium* possessed a complete series of teeth, almost continuously placed, the canines not being excessively developed. The dental formula is—

$$i\,\frac{3—3}{3—3};\ c\,\frac{1—1}{1—1};\ pm\,\frac{4—4}{4—4};\ m\,\frac{3—3}{3—3}=44.$$

The molars and præmolars (fig. 635) resemble those of the Rhinoceros in many points, but the lower molars have

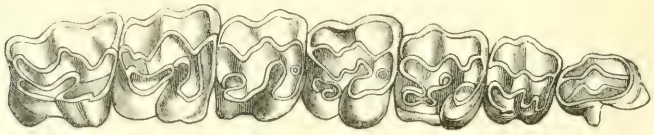


Fig. 635.—Grinding surface of the molar teeth of the upper jaw of *Palæotherium crassum*, one-half the natural size. (After Owen.)

a distinctly doubly-crescentic form. All the præmolars, except the first, resemble the molars in structure. On the other hand, in the genus *Palaplotherium*, abundantly

represented in the Eocene Tertiary, while the general structure was precisely that of *Palæotherium*, the præmolars exhibit a simpler type of structure than the true molars, while the first præmolar is absent.

Through *Anchitherium* the *Palæotheridæ* are brought so close to the *Equidæ*, that it seems probable that the two possessed a common origin.

Fam. 6. *Macrauchenidæ*.—It seems necessary in the meanwhile to establish a separate family for the reception of the curious but still imperfectly known Mammals which constitute the genus *Macrauchenia*, the remains of which have been discovered in the Pliocene or Post-Pliocene deposits of the South American continent. Owing to the fact that the transverse processes of the cervical vertebræ are without a foramen for the passage of the vertebral artery, this anomalous genus was originally referred to the *Camelidæ*, and named accordingly. It is quite certain, however, that the genus must be placed among the Perissodactyles, as all the feet are three-toed, there is a third trochanter to the femur, and the astragalus resembles that of the Odd-toed Ungulates in having no articular facet for the cuboid bone. The dental formula is—

$$i\,\frac{3—3}{3—3};\ c\,\frac{1—1}{1—1};\ pm\,\frac{5—5}{4—4};\ m\,\frac{3—3}{3—3}=46.$$

The teeth form a nearly continuous series; the canines are not excessively developed; the incisors have a deep coronal pit (as in *Equus*); and the lower molars resemble those of *Palæotherium* in being doubly crescentic. The general form of the skull resembles that of the Horses.

Fam. 7. *Equidæ* (*Solidungula* or *Solipedia*).—This family comprises only the existing Horses, Asses, and Zebras, usually comprised in the single genus *Equus;* but along with these we must place a large number of extinct forms, in many cases of an extremely interesting character. In all the recent forms, one of the most striking features is the reduction of the digits to a single perfect toe (the third) on each foot; but this character is not available in characterising the family, since various fossil types show an increase

in the number of the digits. In all, however, the third digit is pre-eminently and symmetrically developed, and the foot is distinctly of the Perissodactyle type, while the femur has a third trochanter. There is a discontinuous series of teeth in each jaw—the præmolars being always separated by a wide diastema (fig. 636) from the teeth in front of them—and canines are usually present in the males only. The dental formula is—

$$i\,\frac{3—3}{3—3};\ c\,\frac{1—1}{1—1}\ \text{or}\ \left(\frac{0—0}{0—0}\right);\ pm\,\frac{3—3}{3—3};\ m\,\frac{3—3}{3—3}=40.$$

The incisors are of moderate and equal size in both jaws, and typically (*Equus* and *Hipparion*) exhibit a deep pit in their crowns; the canines of the males are usually well developed, but not tusk-like; and the molars are extremely long. The outer side of the molars is deeply grooved with

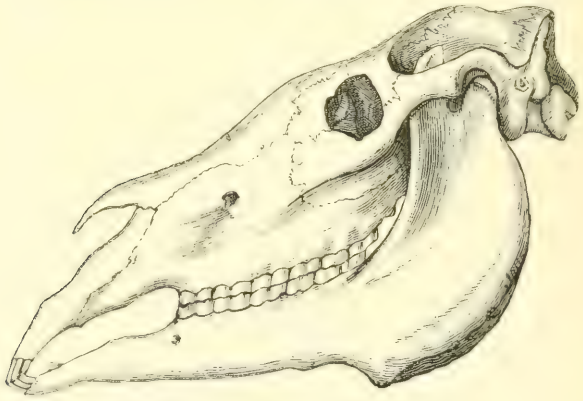


Fig. 636.—Skull of the Horse (*Equus caballus*).

two parallel grooves, the outer wall being thus doubly crescentic in transverse section, while there are two internal ridges corresponding with the external crescents. The valleys separating the crescents are filled up with cement, with which the external surface is also coated. The lower molars are doubly crescentic, and present resemblances to the corresponding teeth in the *Palæotheria*.

As regards the range of the *Equidæ* in *time*, the earliest

known members of this family appear at the commencement of the Eocene period in North America, and in the Middle and Upper Eocene in Europe. These old types are, however, widely removed in some respects from the modern Horses, and the genus *Equus* itself does not appear till the late Miocene or Lower Pliocene be reached. It is in the North American continent that we find the most complete and instructive series of fossil *Equidæ;* though no Horses existed in the New World at the time of its discovery by the Spaniards. It is in the fossil forms of this region, also, that we can trace most clearly the line of connected forms through which we may suppose *Equus* itself to have descended—our knowledge on this subject having been largely increased by the discoveries of Professor Marsh. Many of the fossil *Equidæ* are still only very partially known, and it will be sufficient here to glance at the more important and better understood types alone.

The most ancient member of the *Equidæ* at present known is the *Eohippus*, discovered in the Lower Eocene of New Mexico by Marsh. There is a complete series of teeth, the dental formula being—

$$i\ \frac{3—3}{3—3};\ c\ \frac{1—1}{1—1};\ pm\ \frac{4—4}{4—4};\ m\ \frac{3—3}{3—3} = 44.$$

The last præmolar resembles the præmolar in front of it, instead of the molar behind it. The animals comprised in this genus were of small size,—the fore-feet possessing four toes, *with a rudimentary thumb* in addition; while the hind-feet have only three toes, all the digits terminating in hoofs.

In beds slightly higher than those with *Eohippus* are found the remains of *Orohippus*. This genus comprises small Equine animals, nearly allied to the preceding, and about as large as Foxes. The fore-feet (fig. 637, A) are four-toed, the third digit being the largest; and the hind-feet are three-toed. There is now no trace of the rudimentary pollex of *Eohippus;* and the last præmolar resembles the molars. The dental formula is the same as in *Eohippus*, and the canines are large and separated from the præmolars

by a long diastema. There is no antorbital fossa, such as exists in *Anchitherium*.

In the Lower Miocene of North America we meet with the genus *Mesohippus*, the species of which are about as large as a sheep, but with longer legs. The hind-feet are three-toed, as are the fore-feet also, but the latter possess a "splint-bone" (rudimentary metacarpal) representing the little finger. Two of the præmolars now entirely resemble the molars.

In the Upper Miocene of North America *Mesohippus* is replaced by *Miohippus*, the animals comprised in which are

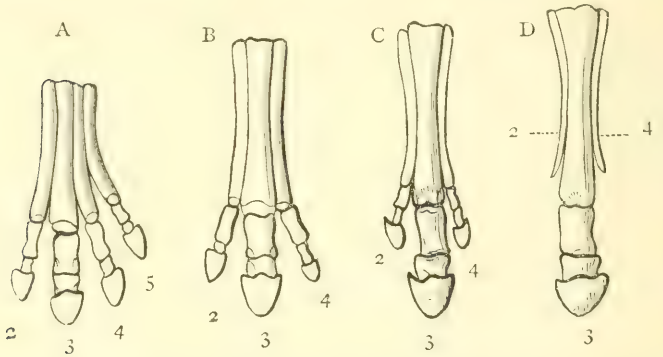


Fig. 637.—Skeleton of the foot in various forms belonging to the family of the *Equidæ*. A, Foot of *Orohippus*, Eocene; B, Foot of *Anchitherium*, Upper Eocene and Lower Miocene; C, Foot of *Hipparion*, Upper Miocene and Pliocene; D, Foot of Horse (*Equus*), Pliocene and Recent. The figures indicate the numbers of the digits in the typical five-fingered hand of Mammals. (After Marsh.)

rather larger than a sheep. This genus is intermediate between *Orohippus* and *Anchitherium*, differing from the former in the fact that there are only three digits to the fore-feet, and from the latter in having no antorbital fossa. All the feet are tridactylous, the toes being nearly of equal size; and the little finger of the hand—functionally developed in *Orohippus*—is here represented by a "splint-bone."

Allied to the preceding is the genus *Anchitherium*, of the European Miocene, in which the species were about as big as a sheep. In many points this genus exhibits Palæotheroid characters, so that it is transitional between the *Equidæ* and

Palæotheridæ. Both the hind and fore feet (fig. 637, B) are three-toed, all the toes being sufficiently developed to touch the ground, but the central toe (third digit) is much the largest. There is likewise no splint-bone representing the fifth digit in the hand; while the genus further differs from *Miohippus* in having a large antorbital fossa.

Another important European type of *Equidæ* is *Hipparion*, which seems to have abounded in Southern Europe during the later Miocene and Pliocene periods. In this genus, the skeleton is like that of the Horse in its general conformation; but the feet, though functionally single-toed, are anatomically three-toed. The central toe (third digit) is now the only toe which touches the ground (fig. 637, C); while the second and fourth digits, though visible externally and furnished with small hoofs, are so much reduced in size as to have taken no part in supporting the weight of the body. The teeth are very horse-like, but an antorbital fossa was present.

In the Lower Pliocene of North America, the place of *Hipparion* is taken by *Protohippus*, some of the species of which equalled the Ass in size, while the structure of the feet resembled that of *Hipparion*.

Of the other Pliocene horses of America, the only one of importance is *Pliohippus*, in which the foot has the same structure as in *Equus* (fig. 637, D). That is to say, the feet have only a single functional toe each, and the second and fourth toes are only represented by rudimentary "splint-bones," concealed beneath the skin. Though agreeing with *Equus* in the structure of its feet, *Pliohippus* differs from this genus in possessing a large antorbital fossa, and in having an additional permanent upper præmolar, the dental formula being—

$$i\,\frac{3—3}{3—3};\ c\,\frac{1—1}{1—1};\ pm\,\frac{4—4}{3—3};\ m\,\frac{3—3}{3—3}=42.$$

Lastly, the genus *Equus* itself seems to have made its first appearance towards the close of the Miocene or the commencement of the Pliocene period. In the Old World the first appearance of true Horses seems to be in the *Equus*

Sivalensis of the Siwâlik Hills, in deposits which are usually regarded as of Upper Miocene age, though there is good reason for rather regarding them as belonging to the Pliocene. In the Pliocene of Europe, North America, and South America, the genus is well represented; and the *Equus fossilis* of the Post-Pliocene and Recent periods is specifically undistinguishable from the existing *Equus caballus*.

CHAPTER XLIII.

UNGULATA (Continued).

Artiodactyla.

Section B. Artiodactyla.—In this section of the Ungulates *the number of the toes is even—either two or four—and the third toe on each foot forms a symmetrical pair with the fourth* (fig. 624, c). *The dorso-lumbar vertebræ are nineteen in number, and there is no third trochanter on the femur. If true horns are present, these are always in pairs, and are supported by bony horn-cores. The antlers of the Deer are also paired, but they are not to be regarded as true horns. The stomach is always more or less complex, or is divided into separate compartments, and the cæcum is comparatively small and simple.* By Kowalewsky the *Artiodactyla,* recent and extinct, are divided into two great groups or sections, in accordance with the nature of the molars. In the one section (*Selenodonta*) the teeth are crescentic, as in the living Ruminants and the extinct *Anoplotheridæ.* In the second group (*Bunodonta*) are the living *Hippopotamidæ* and *Suida,* in which the teeth have tuberculated crowns.

The section *Artiodactyla* comprises the Hippopotamus, the Pigs, and the whole group of the Ruminants, including Oxen, Sheep, Goats, Antelopes, Camels, Llamas, Giraffes, Deer, &c. Besides these there is an extensive series of fossil forms commencing in the Eocene or Lower Tertiary period, and in many respects filling up the gaps between the living forms.

OMNIVORA.

Fam. 1. *Hippopotamidæ.*—This group contains only the single well-marked genus *Hippopotamus*, characterised by the

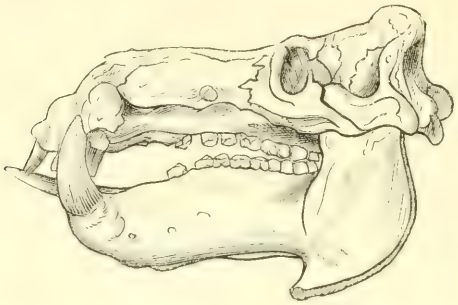


Fig. 638.—Skull of *Hippopotamus amphibius*, side view. (After Giebel.)

massive heavy body, the short blunt muzzle, the large head, and the presence of teeth of three kinds in both jaws (fig. 638). The incisors are $\frac{2—2}{2—2}$, the canines extremely large, $\frac{1—1}{1—1}$, and the molars $\frac{7—7}{7—7}$ or $\frac{6—6}{6—6}$, with crowns adapted for grinding vegetable substances. The upper canines are comparatively short, but the lower canines are in the form of enormous tusks, with a chisel-shaped edge. The feet are massive, and are terminated by four hoofed toes each. The eyes and ears are small, and the skin is extremely thick, and is furnished with few hairs. The tail is very short.

The molar teeth in the Hippopotamus are of the bunodont type, their crowns being tuberculated, and wearing down with use so as to produce a characteristic double trefoil pattern (fig. 639). The number of incisors varies, as regards the lower jaw. In the living forms, *Hippopotamus amphibius* has four lower incisors, and belongs, therefore, to a subgeneric group, which includes also most of the fossil forms, and which has been called *Tetraprotodon*. The only other living member of the family is the small Liberian Hippopotamus,

which has only two lower incisors, and which is, therefore, often placed in a separate genus under the name of *Chœropsis*. Lastly, we have a series of forms from the Upper Miocene of India, which have been raised to the rank of a sub-genus (*Hexaprotodon*), upon the ground that the lower jaw has six incisors (fig. 640, *c*).

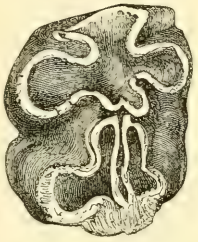


Fig. 639.—Molar tooth of *Hippopotamus*, two-thirds of the natural size. Post-Pliocene.

So far as at present known, the genus *Hippopotamus* is an exclusively Old World type, no member of the group having hitherto been detected in the Tertiary of the American continent. The earliest forms of the genus belong to the section *Hexaprotodon*, and are found in the Upper Miocene deposits of the Siwâlik Hills in India. In the later Tertiaries of Europe several species

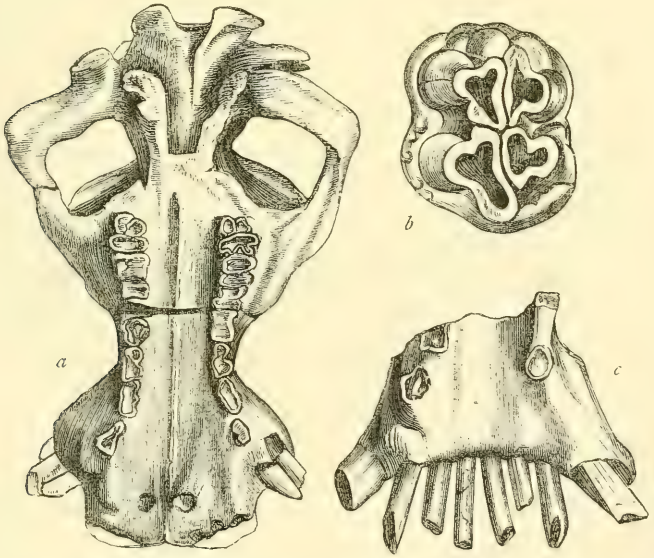


Fig. 640.—*a*, Skull of *Hippopotamus Sivalensis*, viewed from below, one-eighth of the natural size; *b*, Molar tooth of the same, showing the surface of the crown, one-half of the natural size; *c*, Front of the lower jaw of the same, showing the six incisors and the tusk-like canines, one-eighth of the natural size. Upper Miocene, Siwâlik Hills. (After Falconer and Cautley.)

of *Hippopotamus* are known, of which the most important is the *Hippopotamus major* of the Pliocene and Post-Pliocene.

This well-known species is very nearly allied to the living *H. amphibius* of Africa, and it at one time extended its range over the whole of the south of Europe, and abounded in Britain.

By some palæontologists the genus *Merycopotamus*, of the Upper Miocene of the Siwâlik Hills, is referred to the *Hippopotamidæ*, and it certainly has strong affinities with this family. On the other hand, its molars exhibit selenodont characters, which would ally it with the Ruminants, while it has other characters which bring it very close to *Anthracotherium* among the *Suida*.

Fam. 2. *Suida*.—The group of the *Suida*, comprising the Pigs, Hogs, and Peccaries, is very closely allied to the preceding; but the feet (fig. 624) have only two functional toes, the other two toes being much shorter, and hardly touching the ground. All the three kinds of teeth are present, but they vary a good deal. The canines (fig. 641) typically

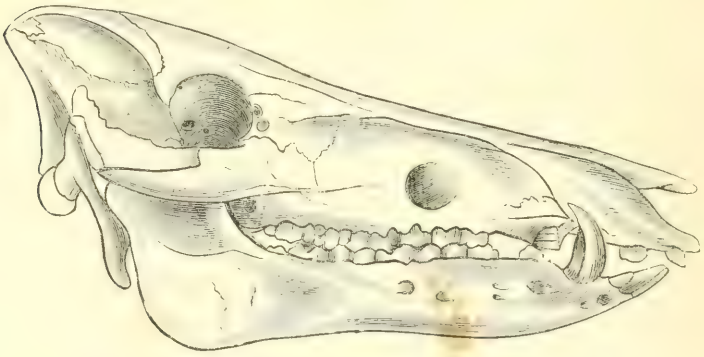


Fig. 641.—Skull of the Wild Boar (*Sus scrofa ferus*). (After Gray.)

are very large, and in the males they usually constitute formidable tusks projecting from the sides of the mouth. The incisors are variable, but the lower ones are always inclined forwards. The molars and præmolars are typically six or seven on each side of the mouth $\left(\frac{6—6}{6—6} \text{ or } \frac{7—7}{7—7}\right)$ and have tuberculate crowns. The stomach is mostly slightly divided, and is not nearly so complex as in the Ruminants.

The snout is truncated and cylindrical, fitted for turning up the ground, and is capable of considerable movement. The skin is more or less abundantly covered with hair, and the tail is very short, or represented only by a tubercle.

As represented at the present day, the family *Suida* is a very well-marked and distinctly circumscribed group of Artiodactyles; but we meet with a large number of extinct types, commencing in the Eocene Tertiary, which show more or less generalised characters, and render it difficult or impossible, in the present state of our knowledge, to sharply separate off the family from the *Hippopotamidæ* on the one hand, and the *Anoplotheridæ* on the other. There are, moreover, extinct types with many Suilline affinities, which show points of resemblance to the Ruminants; and there are others which it may be best to place provisionally in separate groups.

The genus *Sus*, comprising the living Wild Boar and domestic Pig (*Sus scrofa*), may be taken as the type of the family; and its permanent dental formula is—

$$i\ \frac{3—3}{3—3};\ c\ \frac{1—1}{1—1};\ pm\ \frac{3—3}{3—3};\ m\ \frac{3—3}{3—3} = 40.$$

The lower incisors are inclined forwards (fig. 641); the canines of the males are tusk-like; and the molars have broad crowns, with two transverse ridges (three or more in number in the last molar), which are divided into rounded tubercles. In the Peccaries (*Dicotyles*), the leading Suilline type of the New World, the incisors are reduced to four in number in the upper jaw; and the molars, though still distinctly of the bunodont type, present more conspicuous transverse ridges, which are less markedly tuberculated than in *Sus* (fig. 642). On the other hand, in some of the older Tertiary *Suida* we find that the molar teeth exhibit characters intermediate between the bunodont and selenodont types, thus leading us through the family of the Oreodonts to the true Ruminants.

In the genus *Sus* there are four toes to all the feet, but the third and fourth digits form a functionally developed and symmetrical pair, while the second and fifth digits are

rudimentary and do not touch the ground (fig. 624). In the living Peccaries (*Dicotyles*), again, the fore-feet are the same as in *Sus;* but the hind-feet become unsymmetrical by the reduction of the fifth digit to its metatarsal. In the Miocene *Elotherium* the digits on each foot are reduced to the third and fourth, the second and fifth being present only

Fig. 642.—Grinding surface of the molar and præmolar teeth of a Peccary (*Dicotyles labiatus*). (After Giebel.)

in the form of rudimentary "splint-bones," concealed beneath the skin. Lastly, in many of the older Tertiary *Suida* there appear to have been four functionally-useful toes to all the feet, the second and fifth digits reaching the ground as well as the third and fourth.

The genus *Sus* itself appears to have commenced in the Miocene Tertiary, with the *Sus Lockarti* and *S. chœroides* of the Middle Miocene, and the *S. antiquus*, *S. major*, and *S. crymanthius* of the Upper Miocene. The last mentioned of these is a very large Wild Boar which occurs in the Tertiary deposits of Pikermi in Greece. In the Upper Pliocene of France we meet with the *Sus arvernensis*, and the living *Sus scrofa* appears for the first time in the Post-Pliocene deposits of Europe. No species of the genus *Sus* have as yet been detected in North America. The genera *Palæochœrus* and *Hyotherium* of the European Miocene resemble *Sus* proper in most respects, but the tubercles of the molar teeth are more distinctly circumscribed. The Miocene *Amphichœrus* resembled the two genera just mentioned, and differed from *Sus* in not having the last molar excessively developed, and in the simpler type of the tubercles of the molar teeth; but it possessed extremely long canines, which were directed downwards in the upper jaw. Below the Miocene no Pigs of the modern type have been as yet traced in the European area.

The Peccary (*Dicotyles*), as already mentioned, is the

typical American Pig; and in glancing at the forms that preceded it in time, we cannot do better than quote the remarks upon this subject made by Professor Marsh. After stating that the oldest Artiodactyle Ungulate as yet known in North America is the Lower Eocene *Eohyus*, and that this is an ancient representative of the *Suida*, this distinguished palæontologist proceeds as follows:[1]—

"In the beds above, and possibly on the same horizon, the genus *Helohyus* is not uncommon, and several species are known. The molar teeth of this genus are very similar to those of the Eocene *Hyracotherium* of Europe, which is supposed to be a Perissodactyle, while *Helohyus* certainly is not, but apparently a true lineal ancestor of the existing Pigs. In every vigorous primitive type which was destined to survive many geological changes, there seems to have been a tendency to throw off lateral branches, which became highly specialised and soon died out, because they were unable to adapt themselves to new conditions. The narrow path of the persistent Suilline type, throughout the whole Tertiary, is strewn with the remains of such ambitious offshoots; while the typical Pig, with an obstinacy never lost, has held on in spite of catastrophes and evolution, and still lives in America to-day. In the Lower Eocene we have the genus *Parahyus*, apparently one of these short-lived specialised branches. It attained a much greater size than the true lineal forms, and the number of its teeth was much reduced. In the Dinoceras beds, or Middle Eocene, we have still, on or near the true line, *Helohyus*, which is the last of the series known from the American Eocene. All these early Suillines, with the possible exception of *Parahyus*, appear to have had at least four toes, all of usable size.

"In the Lower Miocene, we find the genus *Perchœrus*, seemingly a true Suilline, and with it remains of a larger form, *Elotherium*, are abundant. The latter genus occurs in Europe on nearly the same horizon, and the specimens known from each continent agree closely in general characters. The

[1] Introduction and Succession of Vertebrate Life in America. An Address delivered before the American Association for the Advancement of Science: 1877.

name *Pelonax* has been applied erroneously to some of the American forms; but the specimens on which it was based clearly belong to *Elotherium*. This genus affords another example of the aberrant Suilline offshoots, already mentioned. Some of the species were nearly as large as a Rhinoceros, and in all there were but two serviceable toes, the outer digits, seen in living animals of this group, being represented only by small rudiments concealed beneath the skin. In the Upper Miocene of Oregon, Suillines are abundant, and almost all belong to the genus *Thinohyus*, a near ally of the modern Peccary (*Dicotyles*), but having a greater number of teeth, and a few other distinguishing characters. In the Pliocene, Suillines are still numerous, and all the American forms yet discovered are closely related to *Dicotyles*. The genus *Platygonus* is represented by several species, one of which was very abundant in the Post-Tertiary of North America, and is apparently the last example of a side branch before the American Suillines culminate in the existing Peccaries. The feet in this species are more specialised than in the living forms, and approach some of the peculiar features of the Ruminants; as, for example, a strong tendency to coalesce in the metapodial bones. The genus *Platygonus* became extinct in the Post-Tertiary, and the later and existing species are all true Peccaries."

Leaving the typical *Suida*, we must next glance at a group, or several groups, of Tertiary Mammals, which have strong Suilline affinities, but which have a more or less distinctly selenodont type of dentition, though in a generalised form, and which thus conduct us from the *Suida* to the true Ruminants.

Among the more pig-like of these transitional forms *Anthracotherium* and *Charopotamus* may be specially singled out. In *Anthracotherium* are included a number of Miocene Suillines—all European—in which the dentition is complete, the incisors being strong, the canines moderately large, and the molars (fig. 643, A) having the two transverse lobes which characterise their crowns broken up into four tubercles, while the last molar has an accessory fifth tubercle. The *Chœropotamus* of the Eocene Tertiary shows points of resem-

blance to the modern Peccary, as well as to *Anthracotherium*. The dental formula is—

$$i\ \frac{3—3}{3—3};\ c\ \frac{1—1}{1—1};\ pm\ \frac{4—4}{3—3};\ m\ \frac{3—3}{3—3} = 42.$$

There is thus a præmolar less in the lower jaw than in the preceding genus. The canines are of small size; the molars have four principal tubercles, the last lower molar having two additional accessory tubercles; and the pattern of the præmolars is simpler than that of the molars.

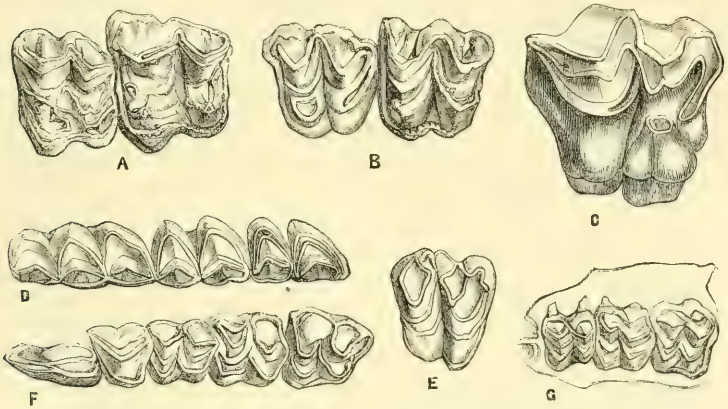


Fig. 643.—A, Grinding surfaces of the last two upper molars on the left side of *Anthracotherium magnum*—Miocene (after Gervais); B, First two upper molars on the left side of *Hyopotamus porcinus*, viewed from above—Eocene (after Gervais); C, Grinding surface of an upper molar of *Anoplotherium commune*—Eocene (after Owen); D, Last three upper molars of *Dichodon cuspidatus*, viewed from above—Eocene (after Owen); E, Grinding surface of an upper molar of the same; F, The five last upper molars on the left side of *Xiphodon gracile*, viewed from above—Eocene (after Gervais); G, The three last left molars of *Dichobune leporinum*—Eocene (after Fraas).

The genus *Hyopotamus*, of the Eocene and Lower Miocene, is regarded by Kowalewsky as the type of a distinct family (the *Hyopotamidæ*); but it undoubtedly possesses close affinities with the genera just noticed. The dentition is complete, and of a generalised selenodont type; the molars (fig. 643, B) terminating in pyramidal lobes, the summits of which are moderately sharp, and the valleys between which are not filled in with cement. The crowns of the lower molars exhibit double crescents, with an internal tubercle; and the upper molars possess an accessory fifth lobe. The

feet are typically tetradactyle, the lateral toes being well developed; but in some forms (*Diplopus*) the second and fifth digits are wanting, and the foot is two-toed.

We have next a group of small Eocene and Miocene Mammals (the *Xiphodontidæ*), which have affinities with the preceding forms, and also with the following group of the *Anoplotheridæ* (especially to *Dichobune* and *Dichodon*); but which likewise exhibit relationships with the Ruminant group of the *Tragulidæ* (Chevrotains). The genus *Xiphodon* itself comprises small Artiodactyle Mammals, with didactyle feet, a short tail, and long and slender limbs. The dentition is complete, the teeth forming a continuous series in both jaws, and the canines being of small size. The molars (fig. 643, F) are of a generalised selenodont type, the lower ones, having "two pairs of crescentic lobes with the convexities turned outwards" (Owen). *Cainotherium* includes small Eocene and Miocene Mammals, also nearly allied to the *Tragulidæ*, which resemble the preceding in most respects, but have the lateral toes developed on all the feet. *Microtherium*, of the Miocene Tertiary of Europe, is also very near to the true Chevrotains, but it differed from these, and agreed with the preceding genera, in having a complete dentition, the dental formula being—

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ p^{m}\,\frac{4-4}{4-4};\ m\,\frac{3-3}{3-3} = 44.$$

The upper molar teeth have three posterior cusps and two anterior, as in *Cainotherium* and *Dichobune*. The presence of this additional posterior cusp in the upper molars is a character shared also by the interesting *Homacodon* of the Upper Eocene of North America, which has a generalised selenodont dentition, though in other respects allied to the Suida.

Fam. 3. *Anoplotheridæ*.—We come next to the family of the *Anoplotheridæ*, which, in the present state of our knowledge, can with difficulty be limited precisely, or sharply separated from some of the groups just noticed. The type of this group is *Anoplotherium* itself, of which there are two or three species known from the Upper Eocene of Europe.

The body in this genus (fig. 644) was slender, the size being about that of the existing Ass, and there was a long tail, the vertebræ of which carried chevron-bones below. The

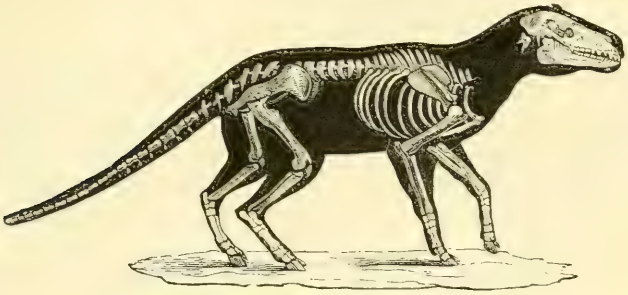


Fig. 644.—*Anoplotherium commune.* Eocene Tertiary.

feet are typically didactyle, no accessory toes being developed, and the metapodials being separate. The dentition is complete, the teeth forming an uninterrupted and continuous series, the crowns being nearly on the same level, and there being no diastema between the canines and the præmolars. The dental formula is—

$$i\ \frac{3—3}{3—3};\ c\ \frac{1—1}{1—1};\ pm\ \frac{4—4}{4—4};\ m\ \frac{3—3}{3—3} = 44.$$

The molar teeth in some respects resemble those of the Rhinoceros, and exhibit generalised selenodont characters. The upper molars (fig. 643, c) have quadrate crowns, divided into two principal lobes, an anterior and posterior, which in turn are less conspicuously bisected by a fore-and-aft depression. The wide valley separating the anterior from the posterior lobe is distinguished by the presence of a large accessory lobe or tubercle at its wide inner entrance. The Miocene genus *Chalicotherium*, which has been shown to occur in North America, China, India, and Europe, is usually placed close to *Anoplotherium;* but it seems questionable if it should not rather be referred to the *Perissodactyla*, and regarded as an ally of the *Tapiridæ* or *Brontotheridæ*. It comprises species as large as the existing Rhinoceroses. *Eurytherium*, also, though with a dentition nearly the same

as that of *Anoplotherium*, is stated to have tridactyle feet, and would thus seem to belong to the Perissodactyle section of the Ungulates.

Of the other Anoplotheroid genera, we need only mention *Dichodon* and *Dichobune*, both of which have marked relations with the *Xiphodontidæ*, and through these with the Ruminant group of the Chevrotains (*Tragulidæ*). The genus *Dichobune*, in particular, is nearly allied to *Xiphodon*, the præmolars being elongated from before backwards, and, except the last, sub-trenchant. There is, however, a slight gap between the canines and præmolars. The genus is from the Eocene of Europe. In the genus *Dichodon*, also from the Eocene, the dentition is likewise complete, and the molars (fig. 643, D and E) have four-lobed crowns, the cusps of which are sharp and conical, while the canines are small, and differ little in size and form from the incisors.

Fam. 4. *Orcodontidæ*.—The last of these transitional groups of Artiodactyles which requires notice is that of the *Orcodontidæ*, comprising a number of curious Ungulates from the Miocene and Pliocene Tertiary of North America, which stand midway between the *Suida* and the *Ruminantia*, and have therefore been appropriately termed "ruminating hogs" by Leidy, though we have no actual evidence to show that they really "ruminated.". In *Orcodon*, the type of the group, we have an even-toed Ungulate, in size about equal to the Sheep, and with characters allying it to the *Suida* on the one hand, and the Deer on the other. The feet were tetradactylous, and the metacarpals and metatarsals were not anchylosed. The dentition is complete, the dental formula being—

$$i\ \frac{3—3}{3—3};\ c\ \frac{1—1}{1—1};\ pm\ \frac{4—4}{4—4};\ m\ \frac{3—3}{3—3} = 44.$$

The incisors are of small size; and the canines are large, trihedral and worn like those of the Pig, and separated by a diastema from the præmolars. The præmolars and molars, on the other hand, are of the Ruminant type, the former exhibiting one crescent, and the latter having the regular doubly-crescentic form of the typical Selenodont Artiodac-

tyles (fig. 645). There is also the anomalous character that "larmiers" or "tear-pits" existed below the orbits, as in the *Cervidæ*. *Oreodon* itself is a Miocene genus, as is the much larger *Eporeodon*. In the Middle Miocene we have the Oreodont genus *Agriochœrus*, which has strong relationships

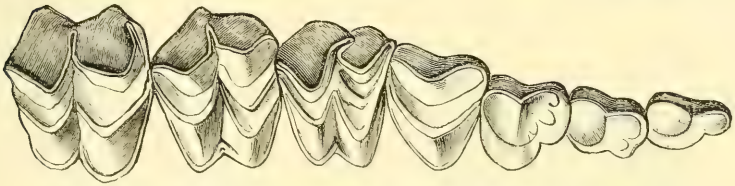


Fig. 645.—Grinding surface of the upper molars and præmolars on the right side of *Oreodon major*. Miocene, North America. (After Leidy.)

with the *Hyopotamus* of the European Eocene; and the family is continued into the Pliocene by the genera *Merychyus* and *Merycochœrus*, after which it disappears altogether.

RUMINANTIA.

The last section of the *Artiodactyle* Ungulates is the great and natural group of the *Ruminantia*, or Ruminant animals. This section comprises the Oxen, Sheep, Antelopes, Giraffes, Deer, Camels, &c., and is distinguished by the following characters:—

The foot is what is called "cloven," consisting of a symmetrical pair of toes encased in hoofs, and looking as if produced by the splitting into two equal parts of a single hoof. In addition to these functional toes, there are usually two smaller lateral digits placed at the back of the foot. The metacarpal bones of the two functional toes of the forelimb, and the metatarsal bones of the same toes of the hindlimb (except in *Hyomoschus*), coalesce to form a single bone, known as the "canon-bone." The stomach is complex, and is divided into several compartments, this being in accordance with their mode of eating. They all, namely, ruminate or "chew the cud"—that is to say, they first swallow their food in an unmasticated or partially-masticated condition, and then bring it up again, after a longer or shorter time, in order to chew it thoroughly.

The dentition of the Ruminants presents peculiarities almost as great and as distinctive as those to be derived from the digestive system. In the typical Ruminants (*e.g.*, Oxen, Sheep, Antelopes), there are no incisor teeth in the upper jaw, their place being taken by a callous pad of hardened gum, against which the lower incisors impinge (fig. 646). There are also

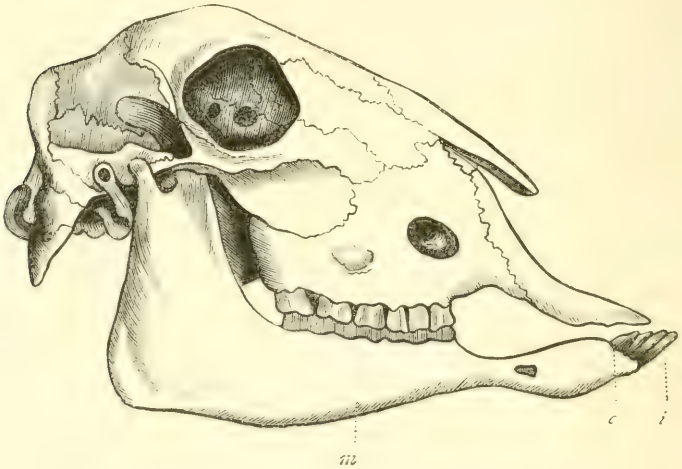


Fig. 646.—Skull of a hornless Sheep (after Owen). *i*, Incisors; *c*, Canines; *m*, Molars and præmolars.

no upper canine teeth, and the only teeth in the upper jaw are six molars on each side. In the front of the lower jaw is a continuous and uninterrupted series of eight teeth, of which the central six are incisors, and the two outer ones are regarded by Owen as being canines. Upon this view, canine teeth are present in the lower jaw of the typical Ruminants, and they are only remarkable for being placed in the same series as the incisors, which they altogether resemble in shape, size, and direction. Behind this continuous series of eight teeth in the lower jaw there is a vacant space, which is followed behind by six grinders on each side. The præmolars and molars are of the "selenodont" type, and have their grinding-surfaces marked with two double crescents, the convexities of which are turned inwards in the upper, and outwards in the lower teeth.

The dental formula, then, for a typical Ruminant animal, is—

$$i\,\frac{0—0}{3—3};\ c\,\frac{0—0}{1—1};\ pm\,\frac{3—3}{3—3};\ m\,\frac{3—3}{3—3}=32.$$

The departures from this typical formula occur in the *Camelidæ*, the *Tragulidæ*, and in some of the Deer. Most of the Deer conform in their dentition to the above formula, but a few forms (*e.g.*, the Muntjak) have canine teeth in the upper jaw. These upper canines, however, are mostly confined to the males; and if they occur in the females, they are of a small size. The dentition of the *Camelidæ* (Camels and Llamas) is still more aberrant, there being two canine-like upper incisors and upper canines as well. The lower canines also are more pointed and stand more erect than the lower incisors, and slightly separated from them, so that they are easily recognisable. The group of the *Ruminantia* includes the families of the *Camelidæ* (Camels and Llamas), the *Tragulidæ* (Chevrotains), the *Cervidæ* (Deer), the *Camelopardalidæ* (Giraffe), and the *Cavicornia* (Oxen, Sheep, Goats, Antelopes).

a. Camelidæ (*Tylopoda*).—The Camels and Llamas constitute in many respects an aberrant group of the *Ruminantia*, especially as regards their dentition and the conformation of the feet. The upper jaw (fig. 647) carries, in the living

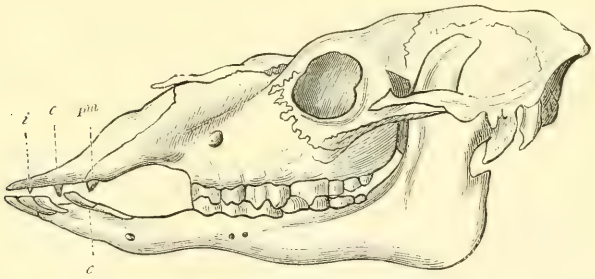


Fig. 647.—Side view of skull of *Camelus Bactrianus*. *i*, Upper incisor; *c*, *c*, Canines; *pm*, Isolated præmolar. (After Giebel.)

forms, three teeth on each side in front, separated by slight intervals. The most anterior of these is a conical incisor; the central one is a canine, and the hindmost is the first

præmolar, which is separated by a wide gap from the rest of the molar series, and is pointed in form. In the lower jaw there is also a canine, placed a little behind the incisors, and a detached laniariform præmolar (the latter sometimes absent). In the Llamas these isolated præmolars are wanting. In the living *Camelidæ* the upper incisors, as we have seen, are reduced to two in number, but in some of the extinct types of the family (*e.g.*, the Pliocene *Protolabis*) we find that the series of incisors is complete, being six in number in each jaw.

The foot in the *Camelidæ* terminates in two toes, furnished with imperfect nail-like hoofs, and the second and fifth toes are wanting. In the Miocene *Poëbrotherium* the metacarpals and metatarsals remain distinct from one another throughout life (as in the living *Hyomoschus*). Horns are not known to have been developed in any of the *Camelidæ*. The *Camelidæ* make their first appearance, so far as known, in the Lower Miocene of North America, where the family is represented by the genera *Poëbrotherium* and *Protomeryx*, the former of these having the embryonic character, that the metapodials do not coalesce to form a "canon-bone." In the Old World, on the other hand, the first recorded appearance of the *Camelidæ* is in the Siwâlik deposits of India, which are generally regarded as of Upper Miocene age. Here we meet with the existing genus *Camelus*. In the Pliocene deposits of North America we have a number of extinct types of the *Camelidæ*. Of these *Procamelus* (fig. 648, B and C) seems to have resembled the true Camels in most respects, and one species was about as large as the existing Camels; but there were four præmolars on each side of each jaw, instead of three only. Though characteristically Pliocene, this genus has also been found in the Miocene of North America. *Homocamelus* resembles the preceding in some respects, but has large canines and isolated first upper præmolars; while *Merycodus* shows some peculiarities in the structure of the molar teeth. In the Pliocene of South America we meet with the two extinct generic types *Palæolama* and *Camelotherium*; and the living genus *Auchenia*, comprising the Llamas and Alpacas, seems to have come into existence at the same time. Remains of

Auchenia are also found in the bone-caves of Brazil, and in the Post-Tertiary of North America (fig. 648, A). At the present day the Llamas are exclusively confined to South America, but they seem to have abounded in the Quaternary

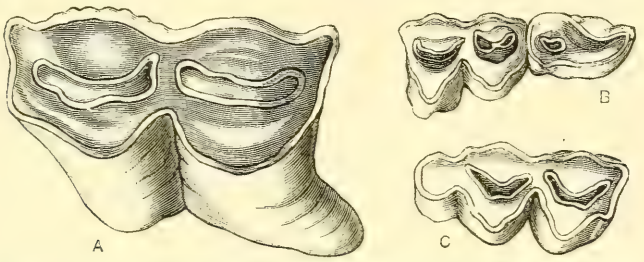


Fig. 648.—A, First molar of *Auchenia hesterna*, viewed from above—Quaternary deposits of California; C, Grinding surface of the last lower molar of *Procamelus Virginiensis*—Miocene, North America; B, Grinding surface of the last præmolar and first molar of the same. All the figures are of the natural size. (After Leidy.)

of North America, and one of the fossil species (*Auchenia hesterna*) seems to have much exceeded both the living species of the genus in size, and to have been larger than the existing Camels. Lastly, in the Drift-deposits of Siberia (of Post-Pliocene age) are found the molar teeth of an extinct genus of *Camelidæ*, to which the name of *Merycotherium* has been given.

b. Tragulidæ.—This group comprises certain small Ruminants, the so-called "Chevrotains" (*Tragulus*), which have been generally associated with the true Musk-deer (*Moschus*) in a single family, under the name of *Moschidæ*. The researches of Milne-Edwards and Flower, however, would prove that *Moschus* itself is really one of the *Cervidæ* or Deer proper, and that the Chevrotains form a group by themselves.

The *Tragulidæ* are characterised by the total absence of horns in both sexes, and by the presence of canines in both jaws, those in the upper jaw (fig. 649) being in the form of tusks in the males, but much smaller in the females. The third stomach, or "psalterium," is wanting, and the placenta is diffuse. The feet have supplementary toes, and the metacarpals of the middle and ring digits either unite in late life to form a canon-bone, or remain (as in *Hyomoschus*) permanently separate.

With regard to the structure and precise affinities of most of the fossil forms which have been referred to the *Tragulidæ*, great uncertainty still obtains, and it is not at present possible to speak very positively as to the precise range of the family in past time. It seems quite possible that the Upper Eocene and Miocene *Xiphodon* and *Cainotherium*, as has been previously noticed, are really referable to the

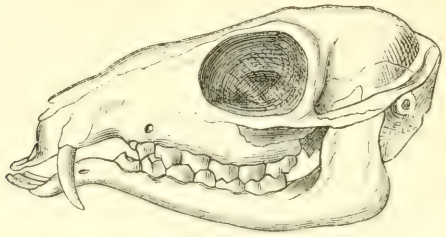


Fig. 649.—Side view of the skull of *Tragulus Javanicus*. (After Giebel.)

Tragulidæ. In the Miocene period in Europe it seems certain that various types of *Tragulidæ* were in existence. Thus the *Dremotherium* and *Amphitragulus* of the Miocene are probably true Chevrotains; and the existing genus *Hyomoschus* has been said to occur in deposits of the same age in France. The genus *Tragulus* itself has not been discovered in the fossil condition, and no remains clearly referable to this family have yet been detected in the Tertiaries of America.

c. Cervidæ.—This family is of much greater importance than that of the *Tragulidæ*, including as it does all the true Deer. They are distinguished from the other Ruminants chiefly by the nature of the horns, which are wanting in the Musk-deer (*Moschus*) and in a few other forms. With the single exception of the Reindeer, these appendages are confined to the males amongst the *Cervidæ*, and do not occur in the females. They do not consist, as in the succeeding group, of a hollow sheath of horn surrounding a central bony core, nor are they permanently retained by the animal. On the other hand, the horns—or, as they are more properly called, the *antlers* — of the *Cervidæ* are deciduous, and are solid. Most usually the antlers are

cast off once a-year, and are reproduced again, this taking place immediately before the breeding season; but some Indian deer do not throw off their horns so often. In the Middle Miocene *Procervulus*, moreover, the horns seem to have been persistent throughout life.

The antlers of the *Cervidæ* are bony throughout, and are produced by a process very similar to that by which injuries of osseous structures are made good in man. Each antler consists of a main stem or "beam," and usually of one or more branches or "tynes," and when first produced they are covered with a finely-haired and vascular integument. When fully formed there is produced, just above the base of attachment to the frontal bone, a circular ridge of bone, which is known as the "burr;" after which the "velvet" or external integument dies and peels off, leaving the antler as a naked process of bone. In the second year after birth in all Deer possessing horns, and in a few forms throughout life, the antlers consist only of the "beam," and are dagger-shaped and unbranched. In the horns of the next year, we find that the beam develops a basal branch or "brow-tyne" (fig. 650, C). This condition of matters may be compared with the permanent form of the antler in the Miocene *Dicroceros* (fig. 650, A), in which there is only a single "tyne" on the "beam." In the next year of life—the fourth after birth—in addition to the "brow-tyne" one or more tynes are developed nearer to the free end of the antler; and we may now compare the state of things to what is permanently the condition of the antler in many of the Pliocene Deer (such as *Cervus Matheroni* and *C. pardinensis*, fig. 650, B). In succeeding years of life, in many Deer, the antlers become, every time they are reproduced, more and more complex, by increase in the number of the "tynes," and by augmentation of their length and size. Lastly, it may be mentioned that in the singular Asiatic Muntjak (*Cervus Muntjak*) the antlers exhibit the peculiarity of being supported upon long bony pedicles or processes of the frontal bones (fig. 650, E).

As regards the distribution of the *Cervidæ*, no undoubted members of the family are known to have existed during

the Eocene period, though some palæontologists are inclined to think that the hornless *Xiphodon* of this period may be an early form of the Deer. It is also possible, as suggested by Marsh, that the *Oromeryx* of the Upper Eocene of North America is an ancestral type of the *Cervidæ*.

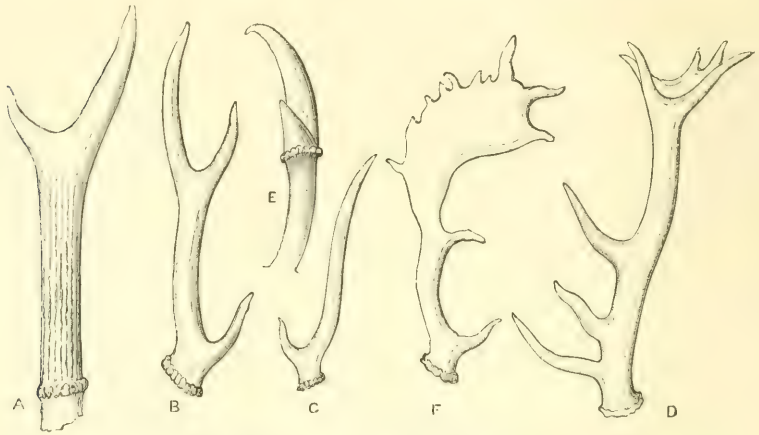


Fig. 650.—A, Antler of *Dicroceros anoceros*—Miocene Tertiary; B, Antler of *Cervus* (*Axis*) *pardinensis*—Pliocene; C, Antler of the Red Deer (*Cervus elaphus*) in the second year; D, Antler of the same in its fully-grown condition; E, Antler and bony pedicle of the frontal bone in the Muntjak (*Cervus Muntjak*); F, Antler of the Fallow Deer (*Dama platyceros*).

In the Miocene deposits of Europe we meet with a number of types of *Cervidæ*, including the recent genus *Cervus*. Most of the forms of this period, however, are extinct, and belong to the genera *Dicroceros* and *Dorcatherium*. In the former of these (fig. 650, A) the antlers appear as if produced by the bifurcation of the "beam" into two divisions. In the Miocene, also, we find the first traces of the true Musk-deer, if *Amphimoschus* be rightly referred to the *Moschidæ*. In the Pliocene period remains of Deer become abundant; and, according to Professor Boyd-Dawkins, they belong to two principal types, represented respectively by the Roebuck (*Capreolus capræa*) of Europe and the Axis Deer of Asia, and most of them resembling the latter. None of the Pliocene Deer belong to species now alive.

In the Post-Pliocene period, we meet with a number of Deer, most of which belong to well-known living types. Of

these, the true Elks, represented by the living Moose (*Alces malchis*, or *A. palmatus*), are distinguished by their antlers without either basal or mesial "tynes," but terminated by a great palmation digitated on its outer side only. Antlers of a species undistinguishable from the existing Moose have been found not uncommonly in Post-Tertiary deposits in various parts of Europe, but this animal does not make its appearance till after the close of the Glacial period.

The Reindeer (*Cervus tarandus*) of Northern Europe and North America is remarkable for being the only member of the *Cervidæ* in which both sexes have horns. The horns are of large size, cylindrical, divided, with basilar and median tynes. Remains of the Reindeer are found, often in considerable abundance, in various Post-Pliocene deposits in Europe, extending as far south as the Pyrenees.

Intermediate between the Reindeer and the Fallow Deer is the celebrated Post-Pliocene species, which is commonly known as the "Irish Elk" (*Cervus megaceros* or *Megaceros Hibernicus*). This extinct form (fig. 651) is remarkable for its great size and for the enormous dimensions of the spreading antlers, which are expanded towards their extremities, and attain an expanse of as much as ten feet from tip to tip. The *Cervus megaceros* is exclusively Post-Tertiary, but does not appear, so far as is known with certainty, to have survived into the Historic period.

The true Stags (*Cervus*), to which the Irish Elk seems properly to belong, are typified by such species as the Red Deer (*Cervus elaphus*) of Europe, and the Wapiti (*Cervus Canadensis*) of North America. The former of these occurs in a fossil state in Post-Pliocene and Recent deposits in Europe, and the latter is represented in accumulations of the same age in America by a closely-allied or identical form. Another remarkable type of Stag, now wholly extinct, is the *Cervus Sedgwickii* of the Norfolk "Forest-Bed" (Post-Pliocene), in which the antlers have a very complicated form.

The Roebuck (*Capreolus capræa*), distinguished by its branched antlers, with a median, but without a basilar, tyne, is also known in a fossil condition in Post-Pliocene deposits in Europe, appearing before the commencement of the

Glacial period. The form of the horns (fig. 652) is one quite peculiar among the existing Deer, but *Cervidæ* with antlers of the Capreoline type have been shown by Boyd-Dawkins to have existed during the Miocene period, so that

Fig. 651.—*Cervus megaceros* (*Megaceros Hibernicus*), the "Irish Elk." Post-Pliocene.

this form of antler must be regarded as one of the most ancient at present known to us. In fact, the Miocene genus *Dicroceros* appears to be an early representative of this type.

d. Camelopardalidæ.—This family includes only a single living animal—the *Camelopardalis Giraffa*, or Giraffe. There are no upper canines in the Giraffe, and both sexes possess two small frontal horns, which, however, are persistent, and

remain permanently covered by a hairy skin, terminated by a tuft of long stiff bristles. These are not mere out-growths of the frontals, but are independent ossifications placed on the sutures between the frontal and parietal bones. There is also a central horn, if it may be so called, which is of the

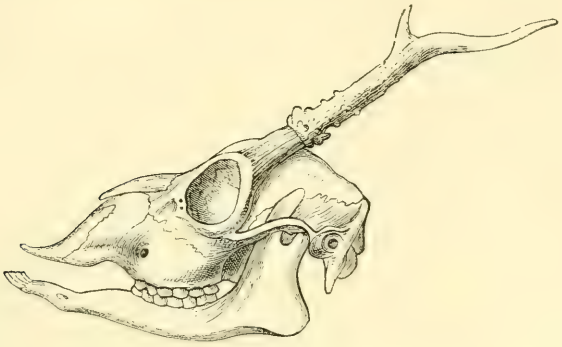


Fig. 652.—Side view of the skull of the Roebuck (*Capreolus capræa*). (After Giebel.)

nature of an epiphysis, and is placed upon the sagittal suture. It becomes early anchylosed with the skull, as do ultimately the other two horns. The neck is of extraordinary length, but, nevertheless, consists of no more than the normal seven cervical vertebræ. The fore-legs appear to be much longer than the hind-legs, and all are terminated by two toes each, the lateral toes being altogether wanting.

Fossil species of Giraffe (*Camelopardalis*) have been discovered in the Tertiary deposits of the Siwâlik Hills in India and in the Upper Miocene of Attica; and a species has also been described from France. This last, however, would seem to be referable to the genus *Helladotherium*, founded for the reception of some singular fossils from the Upper Miocene Tertiary of Attica. In this remarkable genus there appear to have been no horns, and the teeth present certain resemblances to those of the Antelopes. No member of the *Camelopardalidæ* has as yet been discovered in either North or South America, so that this peculiar Ruminant type would appear to be wholly confined to the Old World.

e. Cavicornia.—The last family of the Ruminants is that

of the *Cavicornia*, comprising the Oxen, Sheep, Goats, and Antelopes. This family includes the most typical Ruminants, and those of most importance to man. The upper jaw in all the *Cavicornia* is wholly destitute of incisors and canines, the place of which is taken by the hardened gum, against which the lower incisors bite. There are six incisors and two canines in the lower jaw, placed in a continuous series, and the molars are separated by a wide gap from the canines. There are six molars on each side of each jaw. Both sexes have horns, or the males only may be horned, but in either case these appendages are very different to the "antlers" of the *Cervidæ*. The horns, namely, are persistent, instead of being deciduous, and each consists of a bony process of the frontal bone—or "horn-core"—covered by a sheath of horn. In the Prong-buck (*Antilocapra*), however, the *sheath* of the horn is shed annually. The feet are cleft, but are mostly furnished with accessory hoofs placed on the back of the foot.

The *Cavicornia* comprise the three families of the *Antilopidæ*, *Ovidæ*, and *Bovidæ*. The Antelopes form an extremely large section, with very many species. They are characterised by their slender, deer-like form, their long and slender legs, and their simple, cylindrical, annulated, or twisted horns, which are sometimes confined to the males, but often occur in the females as well.

The above definition will not apply in all points to some singular extinct forms usually referred to the *Antilopidæ*, nor to one aberrant existing form—viz., the Prong-buck (*Antilope furcifer*, or *Antilocapra Americana*). This extraordinary and unique species differs from the typical Antelopes in having no lateral toes, in having horns which have a snag in front, and in the fact that the outer sheath of the horn is *deciduous*, and not permanent. For these reasons, it has been proposed to place the Prong-buck in a separate family (the *Antilocapridæ*); but it is more convenient here to consider it as an aberrant member of the *Antilopidæ*.

The Antelopes do not appear to have a high antiquity, the oldest known forms being from the Upper Miocene of

Greece, and belonging to the living genus *Gazella* and to various extinct types. Of the latter, the genus *Palæoreas* (fig. 653) is supposed to be allied to the living Eland

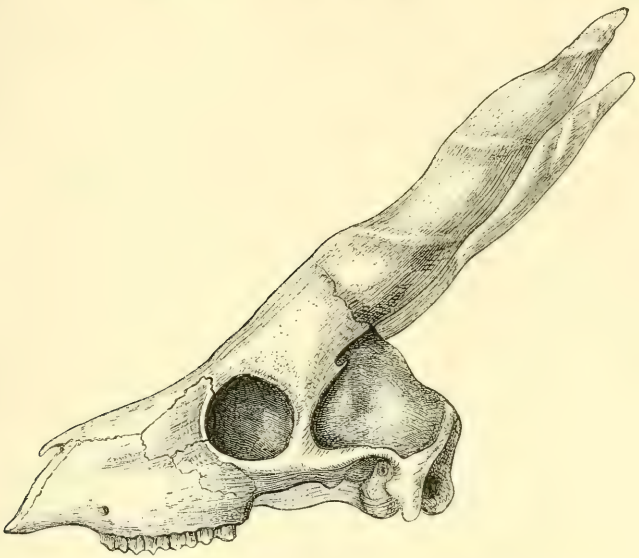


Fig. 653.—Skull of *Palæoreas Lindermayeri*, without the lower jaw, reduced in size. Upper Miocene. (After Gaudry.)

(*Oreas canna*) of South Africa, in which the horns are nearly straight, but have a spiral twist. *Palæoryx*, again, is supposed to be allied to the living Gemsboks (*Oryx*) of Africa, and possessed long curved horns, while *Palæotragus* and *Tragoceras* appear to be true Antelopes, though the latter possesses very Goat-like horns. No important remains of Antelopes of the ordinary type are known from the Pliocene deposits; but remains of a Chamois (*Rupicapra*) have been found in the cave-deposits (Post-Pliocene) of France, and bones of the living genus *Antilope* and the extinct genus *Leptotherium* are said to occur in the bone-caves of Brazil. No North American Antelopes are known as fossils (unless the Pliocene *Cosoryx* be an aberrant type of this family), and there is some doubt as to the reported occurrence of *Antilopidæ* in South America.

By far the most remarkable fossils, however, which have

generally been referred to the *Antilopidæ* are the Upper Miocene (or Lower Pliocene) genera *Sivatherium* and *Bramatherium*.

Sivatherium (fig. 654) is known by the single species *S. giganteum*, discovered by Dr Falconer and Sir Proby Cautley in the Tertiary deposits of the Siwâlik Hills in India. The

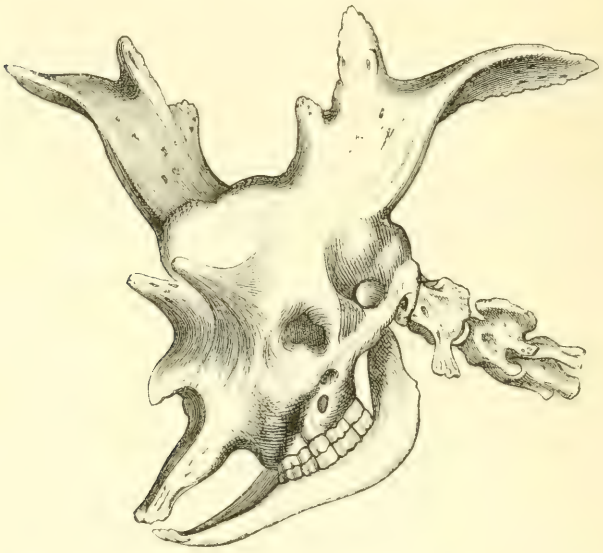


Fig. 654.—Skull of *Sivatherium giganteum*. Upper Miocene, India. (After Murie.)

most important peculiarity in *Sivatherium* is the structure of the horns, of which the animal possessed two pairs. Both pairs of horns were supported by bony "cores," so that there can be no hesitation in referring *Sivatherium* to the group of the *Cavicornia*. The anterior horns, as shown by the shape of the horn-cores, were simple; and if the posterior horns had been of a similar form, then *Sivatherium* might have been fairly regarded as merely a gigantic four-horned Antelope, similar to the living *Antilope* (*Tetraceros*) *quadricornis* of India. The posterior horns, however, are not only much larger than the anterior, but they possess two snags or branches—a peculiarity not to be paralleled amongst existing *Cavicornia*, except in the Prong-buck. Dr Murie, however,

in an admirable paper on the affinities of *Sivatherium*, has drawn attention to the fact that the Prong-buck sheds the sheath of its horns annually, and has suggested that this may have also been the case with the extinct form. This hypothesis is rendered probable, amongst other reasons, by the fact that no sheath has as yet been discovered surrounding the horn-cores of either pair of horns in the *Sivatherium*. Upon the whole, therefore, the above-mentioned zoologist would refer *Sivatherium* to a distinct group which he terms *Sivatheridæ*, and regards as being most nearly related to the *Antilocapridæ*.

Bramatherium has been found in deposits of the same age as *Sivatherium*, with which it agrees in its colossal dimensions and its possession of two pairs of hollow horns. It differs from *Sivatherium*, however, in certain details of minor importance.

The Sheep and Goats (*Ovidæ*) have mostly horns in both sexes, and the horns are generally curved, compressed, and turned more or less backwards. The body is heavier, and the legs shorter and stouter, than in the true Antelopes. In the true Goats (*Capra*) both sexes have horns, and there are no lachrymal sinuses. The true Sheep (*Ovis*) are destitute of a beard, and the horns are generally twisted into a spiral. Horns may be present in both sexes, or in the males only.

The Sheep and Goats are of no importance as fossils, unless, indeed, as believed by high authorities, the Musk-ox should be referred to the *Ovidæ*. Here, however, it will be considered as belonging to the *Bovidæ*. Remains of both Sheep and Goats have been discovered in various Post-Tertiary deposits in Europe, but they present nothing of special interest. No remains of *Ovidæ* are known at present from any deposits older than the Post-Pliocene.

The true Oxen (*Bovidæ*) are distinguished by having simple horns, of a rounded shape, not twisted into a spiral. The oldest known remains of Oxen, so far as known, are those of the Upper Miocene of India, in which we find various extinct species of the living genus *Bos*, together with the extinct genera *Hemibos* and *Amphibos*. In the Pliocene

of Europe we meet with the genus *Bos;* and the American Buffalo is represented as early as the Lower Pliocene by a species of *Bison.* The best known fossil Oxen, however, are those of the Post-Pliocene and Recent periods; and of these the most important are the *Urus,* the Aurochs, the *Bos longifrons* of Owen, and the Musk-ox (*Ovibos*).

The Aurochs or Lithuanian Bison (*Bos bison*) can hardly be considered as a fossil form, as it occurs in a living state in Europe at the present day. Remains, however, of this large ox are found in various prehistoric deposits.

The *Bos longifrons* of Owen, or "Small Short-horn," is in a similar position to the Aurochs. According to Professor Boyd-Dawkins, this form (which is identical with the *Bos frontosus* of Nilsson) has not been proved to occur in any Post-Pliocene deposit, though it occurs plentifully in the bone-caves and alluvia of the Recent or prehistoric period. It is believed by the same high authority that the *Bos longifrons* is the ancestor of our present Welsh and Scotch Cattle.

The *Urus* or Wild Bull (*Bos primigenius*), though much larger than our ordinary oxen, is believed to be specifically

Fig. 655.—Skull of the Urus (*Bos primigenius*). Post-Pliocene and Recent. (After Owen.)

undistinguishable from the domestic Ox (*Bos taurus*), and it was probably the parent of the larger varieties of European Oxen. It was a contemporary of the Mammoth, Woolly Rhinoceros, Cave-lion, Cave-bear, Irish Elk, and other

Post-Pliocene Mammals, and it was in existence up to at least the twelfth century.

The last of the Oxen which deserves notice is the curious Musk-ox (*Ovibos moschatus*). This singular animal is at the present day a native of Arctic America, and is remarkable for the great length of the hair. It is called the Musk-ox, because it gives out a musky odour. Like the Reindeer, the Musk-ox had formerly a much wider geographical range than it has at present—the conditions of climate which are necessary for its existence having at that time extended over a very much larger area than at present. The Musk-ox, in fact, in Post-Tertiary times is known to have extended over the greater part of Europe, remains of it occurring abundantly in certain of the bone-caves of France. As already mentioned, high authorities regard the Musk-ox as being truly a large Sheep, and as being, therefore, referable to the *Ovidæ*.

CHAPTER XLIV.

ORDERS OF MAMMALIA (Continued).

Dinocerata, Tillodontia, and Toxodontia.

Order VII. Dinocerata.—This order comprises certain extraordinary extinct Mammals from the Eocene of North America which are regarded by Professor Cope as an aberrant group of *Ungulates*, whilst Professor Marsh considers them as a distinct order intermediate between the *Perissodactyle Ungulates* and the *Proboscidea*.

The members of this order are all of gigantic dimensions, and of massive construction. *Both the fore and hind feet possessed five well-developed toes, each of which terminated in a hoof. The nasal bones were elongated, and do not seem to have supported a proboscis. The cranium carries three pairs of horn-cores, which were probably enveloped in horny sheaths. There are no upper incisors, and the upper canines have the form of long tusks directed downwards.* (These characters are taken from *Dinoceras*, the best known genus of the group.) The order is distinguished from the *Proboscidea* by the absence of upper incisors, the presence of canines, the possession of three pairs of horn-cores, and the absence of a proboscis.

In *Dinoceras* itself, which may be taken as the type of the group, we have a large animal equal in dimensions to the living Elephants, which it resembles also in the osteology of its limbs, in most essential respects. It is in the skull (fig. 656) and dentition, however, that the most striking peculiarities of *Dinoceras* are to be found. As regards the denti-

tion, the front of the upper jaw was destitute of incisors, and probably carried a palatine pad, but there were two very large canines in the form of tusks directed perpendicularly down-

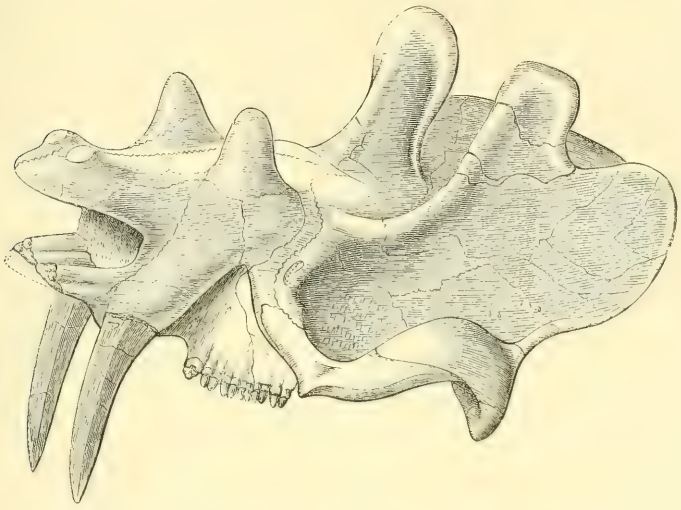


Fig. 656.—Skull of *Dinoceras mirabile* (after Marsh). From the Eocene Tertiary.

wards; and there was also a series of six small molars on each side. In the lower jaw are six incisors, small canines, and twelve præmolars and molars, six on each side. The dental formula is thus—

$$i\ \frac{0—0}{3—3};\ c\ \frac{1—1}{1—1};\ pm\ \frac{3—3}{3—3};\ m\ \frac{3—3}{3—3} = 34.$$

The crowns of the molar teeth exhibit each a pair of oblique ridges, confluent on the inner side of the tooth, but diverging outwardly in a V-like manner. From the very small comparative size of the molars, and the fact that the condyle of the lower jaw is transversely elongated, thus allowing only of up-and-down movement, it has been conjectured that the food of *Dinoceras* must have been of an animal nature. Superiorly each maxillary bone carried a well-developed process, probably of the nature of a horn-core. The nasals support two similar but smaller horn-cores; and

the frontals are developed behind into two larger bony projections, most probably also of the nature of horn-cores. The animal thus possessed three pairs of horns, one carried by the upper jaw-bones, one by the nasals, and one by the frontal bones. Whether, however, these so-called "horn-cores" really supported *horns*, of the nature of the horns of the Cavicorn Ruminants, is quite a matter of conjecture; and there is much probability in the view entertained by Owen—namely, that some of them were simply covered by callous integument.

As regards the mental powers of *Dinoceras*, Professor Marsh remarks: "The brain-cavity of *Dinoceras* is perhaps the most remarkable feature in this remarkable genus. It proves conclusively that the brain (fig. 657, A) was proportionately

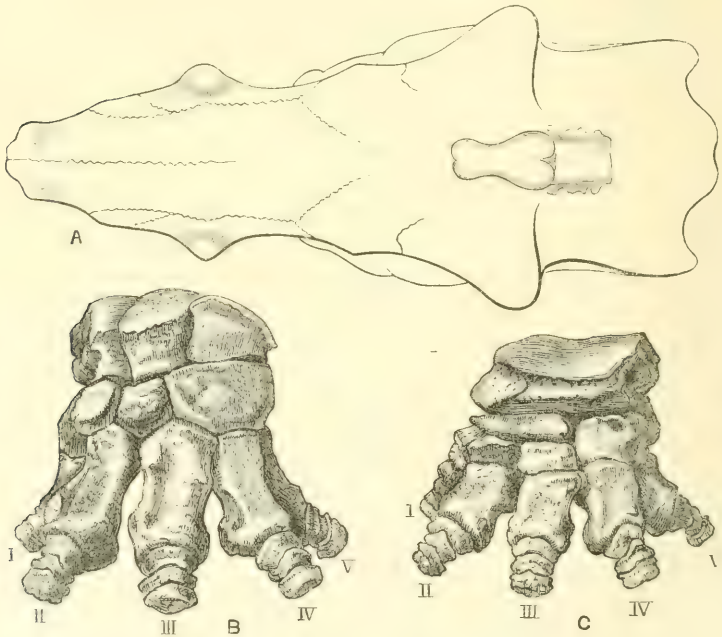


Fig. 657.—A, Skull of *Dinoceras*, viewed from above, showing the form and size of the brain; B, Fore-foot of *Dinoceras*; C, Hind-foot of *Dinoceras*. (After Marsh.)

smaller than in any other known Mammal, recent or fossil, and even less than in some reptiles. It is, in fact, the most

reptilian brain in any known Mammal. In *D. mirabile*, the entire brain was actually so diminutive that it could apparently have been drawn through the neural canal of all the præsacral vertebræ, certainly through the cervicals and lumbars."

The head could be lowered to the ground, and though the nasal bones are elongated, there is no evidence of the existence of a proboscis. The limbs are short, the fore-legs shorter than the hind-legs; and the femur was not provided with a third trochanter. The tail is short and slender, and the ribs are furnished with rudimentary uncinate processes. The feet are furnished with five toes each (fig. 657, B and C), and have a general resemblance to the feet of the Proboscideans. In the hind-foot the hallux seems to have been small or rudimentary. The chief genera included by Marsh among the *Dinocerata* are *Dinoceras*, *Uintatherium*, and *Tinoceras*, the last being stated to be identical with the *Eobasileus* and *Loxolophodon* of Professor Cope. All the remains of this singular group which have been hitherto brought to light are from the Middle Eocene of North America.

Order VIII. Tillodontia.—This order has been established by Professor Marsh for the reception of some singular Mammals from the Eocene Tertiary of the United States. The following are the characters of the order, so far as published: *The molar teeth have grinding crowns, as in Ungulates, and may have distinct roots, or may grow from permanent pulps; small canines are present in both jaws; and each jaw carries two long scalpriform incisors, resembling those of Rodents in form and in growing from persistent pulps. The feet are plantigrade and pentadactyle, and the digits were apparently unguiculate. The femur has a third trochanter, and the radius and ulna and tibia and fibula are distinct bones.*

The order includes two distinct families—one, the *Tillotheridæ*, having molar teeth with distinct roots; whilst the other, *Stylinodontidæ*, possessed rootless molars, which grew from persistent pulps. All the known forms of the order are from the Eocene Tertiary, and the typical species seem to have been from one-half to two-thirds of the size of the Tapir.

The type-genus of the order is *Tillotherium*, which presents a remarkable combination of the characters of the *Ungulata*, *Rodentia*, and *Carnivora*. The general form of the skeleton most closely resembles that of the Carnivores, the skull being like that of the Bears in many respects, whilst the feet are five-toed, with the whole sole applied to the ground, and having ungual phalanges similar to those of the *Ursidæ*. The brain-cavity is of small size, and the cerebral hemispheres did not extend over the cerebellum or the olfactory lobes. The orbits are not complete, but open into the temporal fossæ. The præmolars and molars have grinding crowns, the canines are of small size, and the præmaxillæ carried a pair of large scalpriform incisors (fig. 658), which resemble those

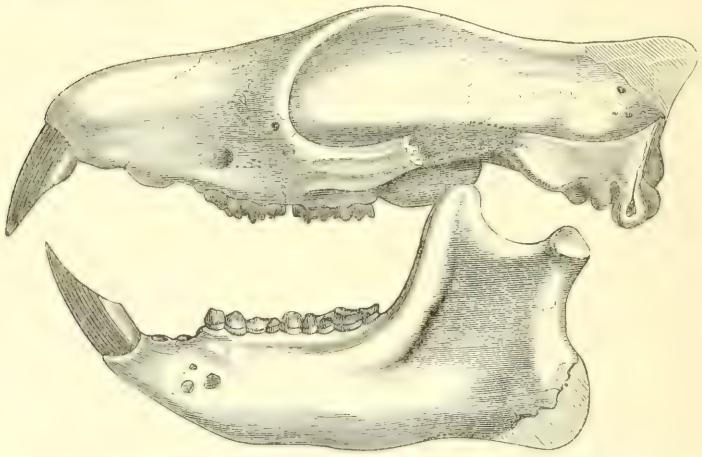


Fig. 658.—*Tillodontia*. Side view of the skull of *Tillotherium fodiens*, with the lower jaw displaced downwards, one-fourth of the natural size. (After Marsh.)

of the Rodents in having chisel-shaped crowns, and in growing throughout the life of the animal. As in Rodents, there is a corresponding pair of scalpriform incisors in the lower jaw. The dental formula is—

$$i\,\frac{2—2}{2—2};\ c\,\frac{1—1}{1—1};\ pm\,\frac{3—3}{2—2};\ m\,\frac{3—3}{3—3}=34.$$

Allied to *Tillotherium* is the *Anchippodus* (= *Trogosus*) of Leidy, from the Eocene deposits of Wyoming.

In the group of the *Stylinodontidae*, besides *Stylinodon* itself, we have the genus *Dryptodon*, in which the dental formula is,

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{3-3}{3-3};\quad m\,\frac{3-3}{3-3}=40.$$

Of the six incisors in each jaw, the four central ones are small, but the outermost ones are huge and compressed, faced with enamel, and growing from persistent pulps. The molars and præmolars are rootless and cylindrical; and the canines are small.

Order IX. Toxodontia.—This order includes certain large extinct Mammals from the later Tertiary deposits of South America, the true systematic position of which is still very doubtful; since they present affinities to the *Ungulata*, the Rodents, and the Edentates. The skull is massive and the dentition is very peculiar. The molars and præmolars are bent so as to be strongly convex outwards and concave inwards, with flat grinding surfaces (fig. 659), and presenting the peculiarity that they are rootless and grow from per-

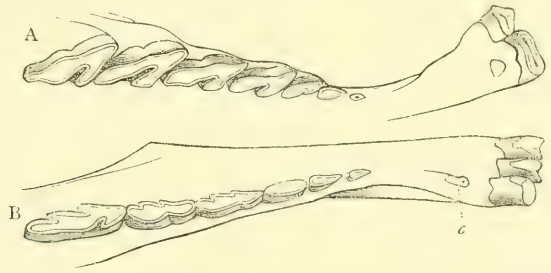


Fig. 659.—A, Right upper jaw of *Toxodon Burmeisteri*, and B, left lower jaw of the same; *c*, Lower canine. (After Burmeister.) Greatly reduced in size.

sistent pulps. Canines are present in the lower jaw, but are of very small size (fig. 659, *c*) and are placed in the interval between the incisors and præmolars. In the upper jaw only the sockets for the canines are left. There are four upper and six lower incisors, which are separated by a wide diastema from the præmolars. The dental formula is—

$$i\,\frac{2-2}{3-3};\ c\,\frac{0-0}{1-1};\ pm\,\frac{4-4}{3-3};\ m\,\frac{3-3}{3-3}=38.$$

There is no third trochanter to the femur, but the structure of the manus and pes is quite unknown.

The genera of this order are *Toxodon* and *Nesodon*, both from late Tertiary or Post-Tertiary deposits in South America. *Toxodon* was about equal to the Hippopotamus in size; and both genera present a combination of characters so extraordinary, that we must await the discovery of more perfect remains before pronouncing any decided opinion as to their true systematic position.

CHAPTER XLV.

ORDERS OF MAMMALIA (Continued).

Hyracoidea and Proboscidea.

Order X. Hyracoidea.—This is a very small order which has been constituted by Huxley for the reception of two or three little animals, which make up the single genus *Hyrax*. These have been usually placed in the immediate neighbourhood of the Rhinoceros, to which they have some decided affinities, and they are still retained by Owen in the section of the Perissodactyle Ungulates.

The order is distinguished by the following characters: *There are no canine teeth, and the incisors of the upper jaw are long and curved* (fig. 660), *and grow from permanent pulps, as they do in the Rodents* (*such as the Beaver, Rat,* &c.) *The molar teeth are singularly like those of the Rhinoceros.* According to Huxley, the dental formula of the aged animal is—

$$i\,\frac{2—2}{2—2};\ c\,\frac{0—0}{0—0};\ pm\,\frac{4—4}{4—4};\ m\,\frac{3—3}{3—3}=36.$$

The fore-feet are tetradactylous, the hind-feet tridactylous, and all the toes have rounded hoof-like nails, with the exception of the inner toes of the hind-feet, which have an obliquely-curved nail. There are no clavicles. The nose and ears are short, and the tail is represented by a mere tubercle.

The living species of *Hyrax* are confined to Africa and Syria; and no fossil forms can at present be referred to

the order, though various extinct genera (such as *Hyracotherium*, *Hyracodon*, &c.) have received names founded on supposed likenesses to the existing *Hyrax*.

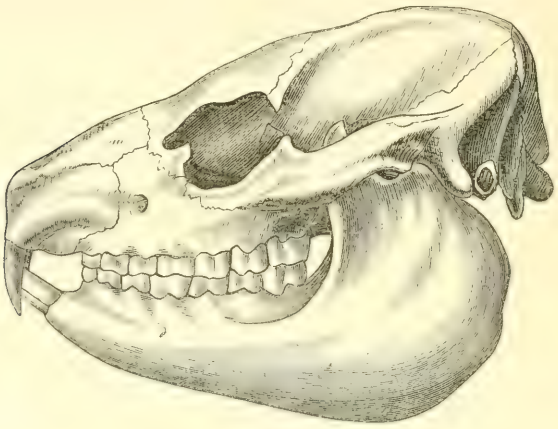


Fig. 660.—Skull of *Hyrax*. (After Cuvier.)

Order XI. Proboscidea.—The eleventh order of Mammals is that of the *Proboscidea*, comprising no other living animals except the Elephants, but including also the extinct *Mastodon* and *Deinotherium*.

The order is characterised by *the total absence of canine teeth; the molar teeth are few in number, large, and transversely ridged or tuberculate; incisors are always present, and grow from persistent pulps, constituting long tusks* (fig. 661). *In living Elephants there are two of these tusk-like incisors in the upper jaw, and the lower jaw is without incisor teeth.* In the *Deinotherium* this is reversed, there being two tusk-like lower incisors and no upper incisors. In the Mastodons, the incisors are usually developed in the upper jaw, and form tusks, as in the Elephants, but sometimes there are both upper and lower incisors, and both are tusk-like. *The nose is prolonged into a cylindrical trunk, movable in every direction, highly sensitive, and terminating in a finger-like prehensile lobe* (fig. 661). *The nostrils are placed at the extremity of the proboscis. The feet are furnished with five toes each*, but some of the toes may be destitute of hoofs.

The recent Elephants are exclusively confined to the tropical regions of the Old World, in the forests of which they live in herds. Only two living species are known—the Asiatic Elephant (*Elephas Indicus*) and the African Elephant (*E. Africanus*).

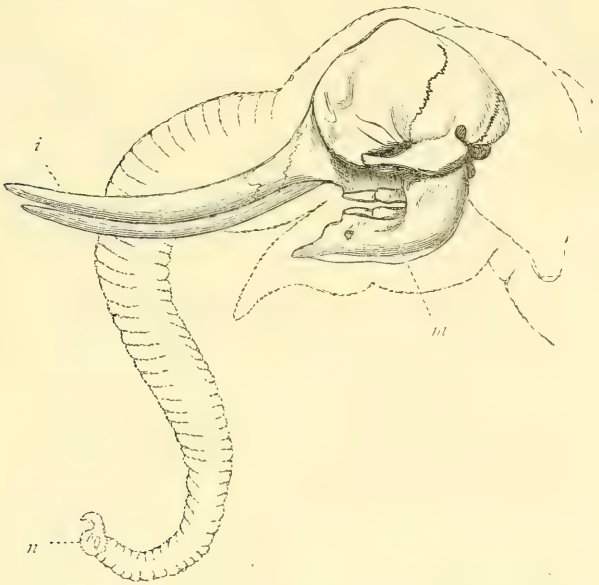


Fig. 661.—Skull of the Indian Elephant (*Elephas Indicus*). *i*, Tusk-like upper incisors; *m*, Lower jaw, with molars, but without incisors; *n*, Nostrils, placed at the end of the proboscis. (After Owen.)

The most important features of the Elephants, from a palæontological point of view, are connected with the nature of the teeth. Canines and lower incisors are invariably wanting, and the "tusks" are formed by an enormous development of the two upper incisors, which are rootless, and continue to grow throughout the life of the animal. The back-teeth are six in number on each side of each jaw, but owing to their great size and the peculiar mode in which they succeed one another, there is never more than one (or at most portions of two) in place and in use at any given moment. The first three teeth of the grinder-series, which would ordinarily represent præmolars, are supposed to be

milk-molars, as they have no predecessors or successors; and the last three are true molars. None of the molars, in fact, undergo vertical displacement (præmolars are present in the extinct *E. planifrons*), but the whole series gradually moves forward in the jaw; and the place of each tooth, as it becomes gradually worn out, is taken by the tooth next behind it in the series. As regards their form, the molars of the Elephants are extremely massive, with an exceptional vertical development, and composed essentially of transverse laminæ of enamel and dentine, more or less copiously united by a coating of cement. The grinding surface of the tooth is always crossed (fig. 662) by more or less numerous ridges,

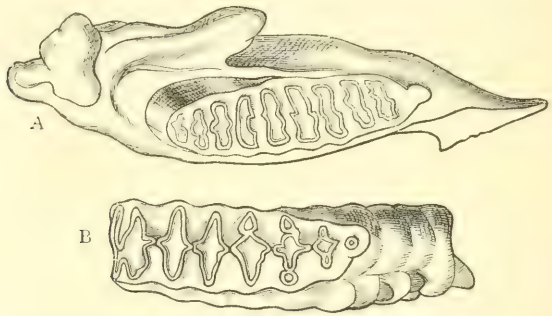


Fig. 662.—A, Left ramus of lower jaw of *Elephas* (*Euelephas*) *Indicus*, viewed from above (after Cuvier); B, Grinding surface of molar tooth of *Elephas* (*Loxodon*) *Africanus* (after Giebel).

consisting centrally of dentine, surrounded with an external layer of enamel, and these ridges are sometimes seen to be obviously composed of a transverse and more or less confluent series of tubercles. The triturating surface of the molars, when worn down by use, is more or less flat, and the transverse ridges of enamel and dentine give rise to various patterns, which are highly characteristic of different species of the genus.

In accordance with the structure of the molar teeth and the form and number of the dental plates, Dr Falconer has divided the genus *Elephas* into three sections, which are sufficiently useful to be introduced here, though it must be admitted that they are to some extent founded upon an artificial basis, and that there are so many transitional forms

as to render it impossible to limit them with absolute precision. The three sections in question are the following:—

1. *Euelephas.*—Dental lamellæ narrow and compressed, the number of the ridges successively increasing in the three true molars from before backwards. The type of this section is the living *Elephas Indicus* (fig. 662, A), the "ridge-formula" of which is 12 + 16 + 24—that is to say, there is a progressive increase in the number of the transverse enamel-ridges of the true molars, the first having twelve of these ridges, the second sixteen, and the third and last twenty-four. Besides the living Asiatic Elephant, the section *Euelephas* includes the Post-Pliocene Mammoth (*E. primigenius*, fig. 663), the *Elephas antiquus* of the

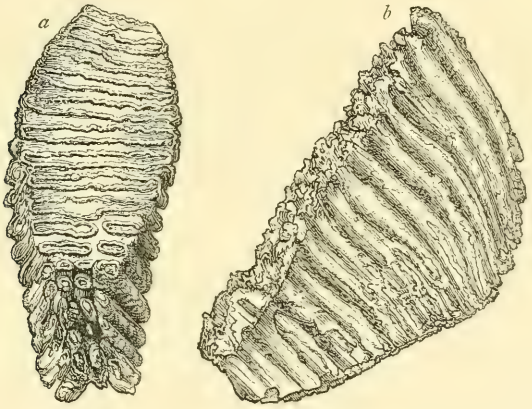


Fig. 663.—Molar of the Mammoth (*Elephas primigenius*), upper jaw, right side, half natural size. Post-Pliocene. *a*, Grinding surface; *b*, Side view.

European Pliocene and Post-Pliocene (fig. 666), and the *Elephas hysudricus* of the Upper Miocene of the Siwâlik Hills, besides other forms of less importance.

2. *Loxodon.*—Dental lamellæ lozenge-shaped or diamond-shaped, not greatly different in number in the three true molars. The type of this group is the living *Elephas Africanus* (fig. 662, B), in which the "ridge-formula" is 7 + 8 + 10. Among the other forms belonging to this section may be mentioned *Elephas planifrons* (fig. 664) of the Upper Miocene (Siwâlik formation) of India, *E. meri-*

dionalis of the European Pliocene (fig. 665), and the Post-Pliocene *E. Melitensis* of Malta.

3. *Stegodon.*—Molars with mammillated tubercles arranged in transverse rows, the number of which is nearly equal in

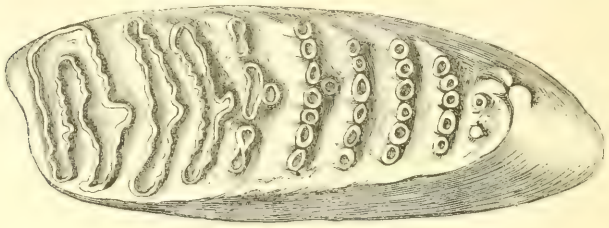


Fig. 664.—Grinding surface of molar tooth of *Elephas planifrons*, one-third of the natural size. Upper Miocene, India. (After Falconer.)

all the molars. The "ridge-formula" of *Elephas* (*Stegodon*) *insignis* is $7 + 8 + 10$. The amount of cement in the molars is much less than in *Euelephas* and *Loxodon*, and the prominence of the ridges is very conspicuous. The section may be regarded as intermediate between the typical Elephants and the Mastodons, and it comprises the extinct *Elephas Cliftii*, *E. bombifrons*, *E. Ganesa*, and *E. insignis* of the Upper Miocene (Siwâlik formation) of India, the last mentioned of these extending its range into the Pliocene of the same country.

The Elephants appear for the first time in the Upper Miocene (Siwâlik formation) of India, in which we meet with types of all the three sections of the genus (*Euelephas*, *Loxodon*, and *Stegodon*). In the Pliocene period, we find species of Elephants widely distributed over Britain, Europe, Asia, and North America. Of the European Elephants of this period, one of the most important is the *Elephas* (*Euelephas*) *antiquus*, a molar tooth of which is here figured (fig. 666).

This is essentially a southern form, and is found in Pliocene strata in France and Italy. It survived the Glacial period, and is found abundantly in various Post-Pliocene deposits. It abounded in Post-Pliocene times chiefly in Southern Europe, south of the Alps and Pyrenees; and it is

only on the northern edge of this area that its remains are found commingled with those of the Mammoth.

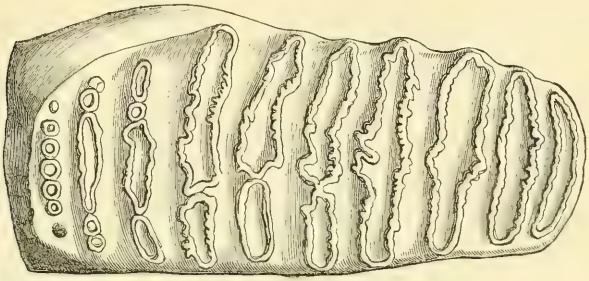


Fig. 665.—Molar tooth of *Elephas* (*Loxodon*) *meridionalis*, one-third of natural size. Pliocene and Post-Pliocene. (After Lyell.)

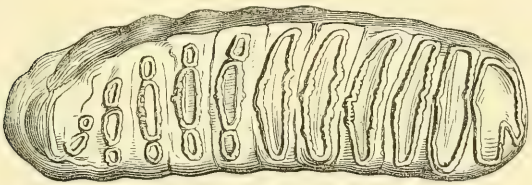


Fig. 666.—Molar tooth of *Elephas* (*Euelephas*) *antiquus*. Penultimate molar, one-third of natural size. Post-Pliocene and Pliocene. (After Lyell.)

Another species from the same area is the *Elephas* (*Loxodon*) *meridionalis*, the enamel plates of which are very thick (fig. 665). Its remains have been found in Britain, France, and Italy.

In the Post-Pliocene, remains of Elephants are numerous, but of these by far the best known and most important is the Mammoth (*Elephas primigenius*). This remarkable form (fig. 667) was essentially northern in its distribution, never passing south of a line drawn through the Pyrenees, the Alps, the northern shores of the Caspian, Lake Baikal, Kamschatka, and the Stanovi Mountains (Dawkins). It occurs in the Præ-glacial forest-bed of Cromer in Norfolk, survived the Glacial period, and is found abundantly in Post-glacial deposits in France, Germany, Britain, Russia in Europe, Asia, and North America, being often associated with the Reindeer, Lemming, and Musk-ox. That it sur-

vived into the earlier portion of the human period is unquestionable, its remains having been found in a great number of instances associated with implements of human manufacture; whilst in one instance a recognisable portrait of

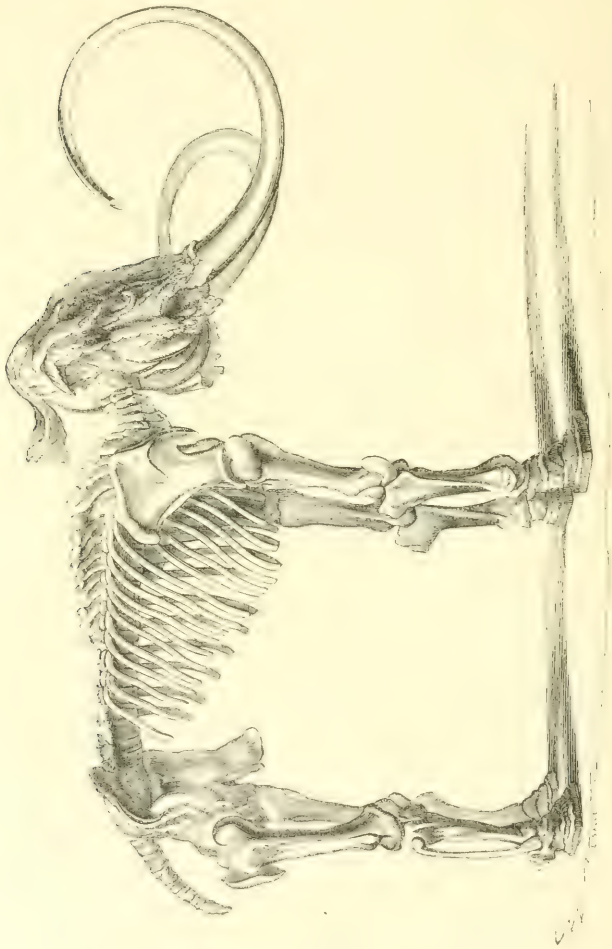


Fig. 667.—Skeleton of the Mammoth (*Elephas primigenius*). Portions of the integument still adhere to the head, and the thick skin of the soles is still attached to the feet. Post-Pliocene.

it has been discovered, carved on bone. From its great abundance in Siberia, it might have been safely inferred that the Mammoth was able to endure a much colder climate than either of the living species. This inference, however,

has been rendered a certainty by the discovery of the body of more than one Mammoth embedded in the frozen soil of Siberia. These specimens had been so perfectly preserved that even microscopical sections of some of the tissues could be made; and in one case even the eyes were preserved. From these specimens, we know that the body of the Mammoth was covered with a thick coat of reddish-brown wool, some nine or ten inches long, interspersed with coarse black hair more than a foot in length. The molars of the Mammoth are of the *Euelephas* type (fig. 663), and the tusks are bent almost into a circle, and may be as much as twelve feet in length. In size, the Mammoth considerably exceeded the largest of the living Elephants, the skeleton being over sixteen feet in length, exclusive of the tusks, and measuring nine feet in height.

Amongst other Elephants which occur in Post-Pliocene deposits may be mentioned, as of special interest, the pigmy Elephants of Malta. One of these—the *Elephas Melitensis*, or so-called "Donkey-elephant"—was not more than four and a half feet in height. The other—the *Elephas Falconeri* of Busk—was still smaller, its average height at the withers not exceeding two and a half to three feet.

The *Mastodons* in most respects closely resemble the true Elephants, from which they are distinguished by their dentition. As in the Elephants, the upper incisors grow from permanent pulps, and constitute long tusks (fig. 668); but in the majority of cases the Mastodons also possess lower incisors as well. The two lower incisors, however, though tusk-shaped, did not develop themselves to any extent, and often disappeared in adult life. A more important distinction between the Elephants and Mastodons is that the molar teeth of the latter are not only more numerous (as regards the number present in the jaw at any given moment), but have the peculiarity that their crowns are furnished with nipple-shaped eminences or tubercles placed in pairs, forming a number of transverse ridges (fig. 668, B). Each of the three molars possesses a like or nearly like number of these ridges, but this number varies in different species, and is always much smaller than in the true Elephants. In

accordance with this, Dr Falconer divided the Mastodons into two principal sections, which he named respectively *Trilophodon* and *Tetralophodon*. In the first of these are such forms as *M. giganteus* (fig. 668, B) of the Post-Pliocene,

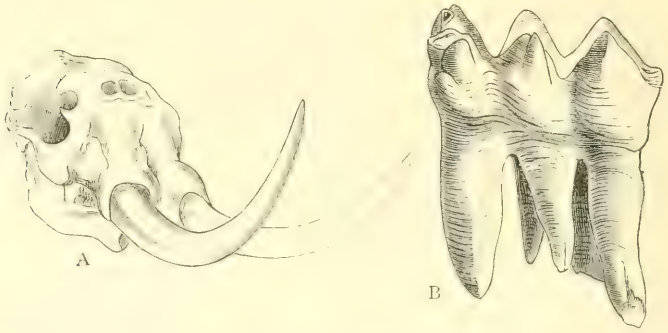


Fig. 668.—A, Skull of *Mastodon giganteus* (= *M. Ohioticus*); B, Side view of the second true molar of the same. (After Owen.)

M. tapiroides and *M. angustidens* of the Miocene, &c., in which there are three ridges to the molars. In the second group, on the other hand, are such forms as the Miocene *M. longirostris* and *M. latidens*, and the Pliocene *M. Arvernensis*

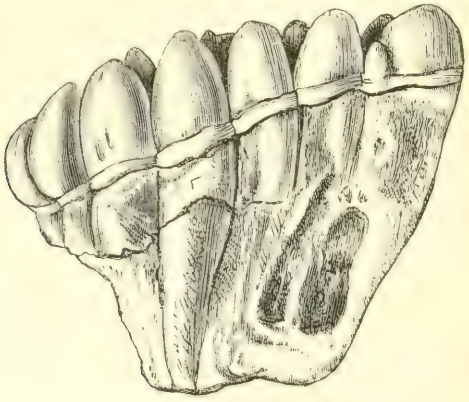


Fig. 669.—Profile view of the last upper molar of *Mastodon Sivalensis*, one-third of the natural size. From the Upper Miocene of India. (After Falconer.)

(fig. 670), in which the molars are four-ridged. Lastly, in *M. Sivalensis* (fig. 669) we have a form in which the molars

are five-ridged, the last being six-ridged; and for this type Dr Falconer proposed the name of *Pentalophodon.*

Fig. 670.—Third milk-molar of the left side of the upper jaw of *Mastodon Arvernensis*, showing the grinding surface. Pliocene. (After Lyell.)

The distribution of the genus *Mastodon* in time is somewhat peculiar, since it commenced both in Europe and Asia in the Miocene, and died out in the Pliocene; whereas in America it does not seem to have made its appearance till the Pliocene, and it survived throughout the whole of the Post-Pliocene period. It is clear, then, that *Mastodon*, like *Elephas*, originated within the Old World, and reached the New World by migration at a later date. Both the Trilophodont and Tetralophodont types of the genus appear to have been represented in the Miocene period, the former being represented by the *M. tapiroides* and *M. angustidens* of the Upper Miocene of Europe, and the latter by the *M. longirostris* of Europe, and the *M. latidens* and *M. Perimensis* of India; while the Pentalophodont type is represented in the Upper Miocene (Siwâlik formation) of India by *M. Sivalensis.* In the Pliocene of Europe the best known forms are the *M.* (*Tetralophodon*) *Arvernensis* of Britain and the continent of Europe, the *M. Andium* of South America, and the *M.* (*Tetralophodon*) *mirificus* of North America. In the European and Asiatic areas, as before remarked, no members of the genus *Mastodon* have hitherto been detected in deposits newer than the Pliocene; but in North America the great *Mastodon giganteus* or *M. Ohioticus* abounded in the

Post-Pliocene period, and another species existed during the same time in South America. *M. giganteus* ranged from Canada to Texas, and very perfect specimens have been exhumed from morasses and swamps, large individuals attaining a length of seventeen feet (exclusive of the tusks), the height being eleven feet, and the tusks twelve feet in length.

The last of the *Proboscidea* is the singular *Deinotherium* of the Miocene, which presents certain points of resemblance to the Sirenians, and is sometimes referred to that order.

Fig. 671.—Skull of *Deinotherium giganteum*. Miocene Tertiary.

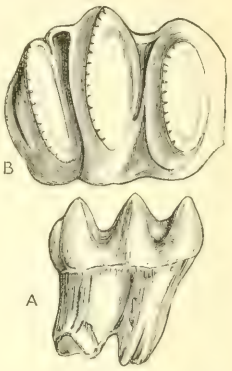


Fig. 672.—A, Side view of the third molar of *Deinotherium giganteum*; B, Grinding surface of the same. Miocene Tertiary. (After Kaup.)

The genus is principally known by the huge skull of the only certainly determined species—namely, *D. giganteum* (fig. 671). The most noticeable feature in the skull is the presence in the lower jaw of two enormous tusk-like incisors, which are directed vertically downwards, in consequence of the abrupt downward flexure of the front portion of the mandible. No canines are present in either jaw, and there are apparently no upper incisors; but both jaws possess a series of præmolars and molars, the whole of which are in use at one time, the milk-molars being displaced by vertical successors in the usual manner. The crowns of the molars are crossed by strong transverse ridges (fig. 672), and exhibit marked Tapiroid characters, while in some respects they resemble

the molars of the Mastodons. The animal must have attained an enormous size, and it is probable that the curved tusks were used either in digging up roots or in mooring their possessor to the banks of rivers, for its habits were probably aquatic or semi-aquatic. The little that is known of the skeleton, except the skull, would confirm the reference of the genus to the *Proboscidea.*

Deinotherium is only known from the Miocene deposits, and *D. giganteum* seems to be the only species. Its remains are found in Germany, France, and Greece, but it has not been discovered in America, and probably did not exist in the New World.

CHAPTER XLVI.

ORDERS OF MAMMALIA (Continued).

Carnivora.

Order XII. Carnivora.—The twelfth order of Mammals is that of the *Carnivora*, comprising the *Feræ*, or Beasts of Prey, along with the old order of the *Pinnipedia*, or Seals and Walruses, these latter being now universally regarded as merely a group of the *Carnivora* modified to lead an aquatic life.

The *Carnivora* are distinguished by always possessing *two sets of teeth, which are simply covered by enamel, and are always of three kinds—incisors, canines, and molars—differing from one another in shape and size. The incisors are generally* $\frac{3—3}{3—3}$ *(except in some Seals); the canines are always* $\frac{1—1}{1—1}$, *and are invariably much larger and longer than the incisors. The præmolars and molars are mostly furnished with cutting or trenchant edges; but they graduate from a cutting to a tuberculate form, as the diet is strictly carnivorous, or becomes more or less miscellaneous.* In the typical Carnivores (such as the Lion and Tiger), the last tooth but one in the upper jaw and the last tooth in the lower jaw are known as the "carnassial" teeth, having a sharp cutting edge adapted for dividing flesh, and generally a more or less developed tuberculated heel or internal process. A varying number, however, of the molars and præ-

molars may be "tuberculate," their crowns being adapted for bruising rather than cutting. As a general rule, the shorter the jaw, and the fewer the præmolars and molars, the more carnivorous is the animal. The jaws are so articulated as to admit of vertical but not of horizontal movements; the zygomatic arches are greatly developed to give room for the powerful muscles of the jaws; and the orbits are not separated from the temporal fossæ. The intestine is comparatively short.

In all the *Carnivora the clavicles are either altogether wanting, or are quite rudimentary. The toes are provided with sharp curved claws.*

The order *Carnivora* is divided into three very natural sections:—

Section I. Pinnigrada or *Pinnipedia.*—This section comprises the Seals and Walruses, in which the fore and hind limbs are short, and are expanded into broad webbed swimming-paddles (fig. 673, B). The hind-feet are placed very

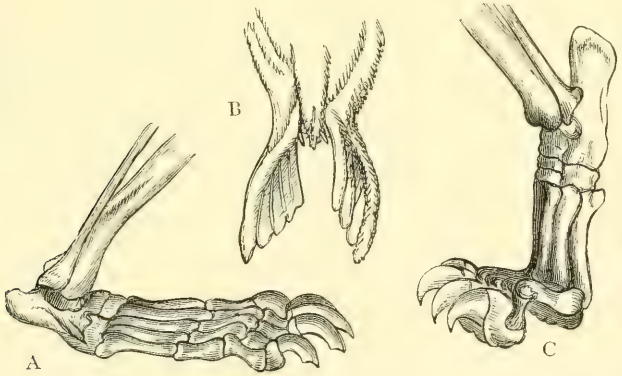


Fig. 673.—Feet of *Carnivora* (after Owen). A, *Plantigrada*, Foot of Bear; B, *Pinnigrada*, Hind-feet of Seal; C, *Digitigrada*, Foot of Lion.

far back, nearly in a line with the axis of the body, and they are more or less tied down to the tail by the integuments.

Section II. Plantigrada. — This section comprises the Bears and their allies, in which the whole, or nearly the whole, of the foot is applied to the ground, so that the animal walks upon the *soles* of the feet (fig. 673, A).

Section III. Digitigrada.—This section comprises the Lions, Tigers, Cats, Dogs, &c., in which the heel of the foot is raised entirely off the ground, and the animal walks upon the tips of the toes (fig. 673, c).

As regards their general distribution in time, if the little *Microlestes* of the Upper Trias be *Marsupial*, as is almost certainly the case, then the order *Carnivora* is comparatively modern, the earliest undoubted remains having been found in the Eocene Tertiary. In the Eocene period, however, the families of the *Canidæ*, *Viverridæ*, and *Felidæ* appear to have been already differentiated. The *Ursidæ*, *Mustelidæ*, *Hyænidæ*, and *Phocidæ*, do not seem to have made their appearance before the Miocene period. In the Pliocene and Post-Pliocene periods almost all the existing types of the *Carnivora* are represented by extinct forms, whilst in the latter the remains of various living species are found associated with other animals which have at the present day entirely passed away. In the following are given the characters and chief fossil forms of the families of the *Carnivora*.

Section I. Pinnigrada.—This section of the *Carnivora* comprises the amphibious Seals and Walruses, which differ from the typical Carnivores merely in points connected with their semi-aquatic mode of life. The body is elongated, somewhat fish-like in shape, and terminated by a short conical tail. All the four limbs are present, but they are very short, and the five toes of each foot are united by the integuments, so as to form powerful swimming-paddles. The hind-feet are placed very far back, their axis nearly coinciding with that of the body (fig. 673, b). Owing to this circumstance the hinder end of the body forms an admirable swimming apparatus, similar in its action to the horizontal tail-fin of the *Cetacea* and *Sirenia*. The dentition varies; but teeth of three kinds are always present, in the young animal at any rate. The canines are always long and pointed, and the molars are generally furnished with sharp cutting edges. There is always a diminution of the incisors below their normal number of six in each jaw, and the molars are never divided into carnassials and tubercular molars.

The Seals (*Phocidæ*) and Sea-lions (*Otaria*) are distinguished by having incisor teeth in both jaws, and by the fact that the canines are not immoderately developed. As regards their distribution in time, the Seals are indicated as occurring in the Miocene (*Otaria*) and Pliocene Tertiary (*Pristiphoca*); but their remains are by no means as abundant as might have been anticipated from their aquatic habits. Remains of Seals, however, are by no means very rare in Post-Tertiary deposits.

The Walruses (*Trichecidæ*) are distinguished from the Seals by their enormously-developed upper canines, which grow from persistent pulps, and constitute great pointed tusks. Remains of large Pinnigrade Carnivores (*Trichecodon*) have been described from the Pliocene Tertiary of Europe, and appear to be nearly allied to the existing Walrus (*Trichecus*).

Section II. Plantigrada.—The Carnivorous animals belonging to this section apply the whole or the greater part of the sole of the foot to the ground (fig. 673, A); and the portion of the sole so employed is destitute of hairs in most instances (the sole is hairy in the Polar Bear).

The typical family of the Plantigrade *Carnivora* is that of the *Ursidæ* or Bears, in which the entire sole of the foot is applied to the ground in walking. The *Ursidæ* are much less purely carnivorous than the majority of the order, and, in accordance with their omnivorous habits, the teeth do not exhibit the typical carnivorous characters. The incisors and canines have the ordinary carnivorous form, but the "carnassial" or sectorial molar has a tuberculate crown instead of a sharp cutting edge. The dental formula is—

$$i\,\frac{3—3}{3—3};\ c\,\frac{1—1}{1—1};\ pm\,\frac{4—4}{4—4};\ m\,\frac{2—2}{3—3} = 42.$$

The claws are large, strong, and curved, but are not retractile. The tongue is smooth; the ears small, erect, and rounded; the tail short; the nose forms a movable truncated snout; and the pupil is circular.

The Bears make their appearance at a comparatively late date, the oldest known types being referable to the genus

Hyænarctos, which commences in the Miocene. Species of *Hyænarctos* are found in the Miocene of France, and in the Tertiary deposits of the Siwâlik Hills in India, and also in the Pliocene of Europe and South America, so that the range of the genus is very extensive. The Miocene genus *Amphicyon*, though resembling the Bears in being plantigrade and a climber, is best considered as an aberrant member of the *Canidæ*. The *Arctotherium* of the late Tertiary deposits of South America seems to be related to the living "Spectacled Bear" of Chili; and the existing genus *Ursus* is represented in the Pliocene of Europe and India, one of the best known forms being the *Ursus Arvernensis* of France. In the Post-Tertiary period the two most important species are the *Ursus priscus* and *Ursus spelæus*, of which the former is apparently identical with the living Grizzly Bear (*Ursus ferox*). The Cave-bear (*Ursus spelæus*, fig. 674) is a gigantic Bear, which,

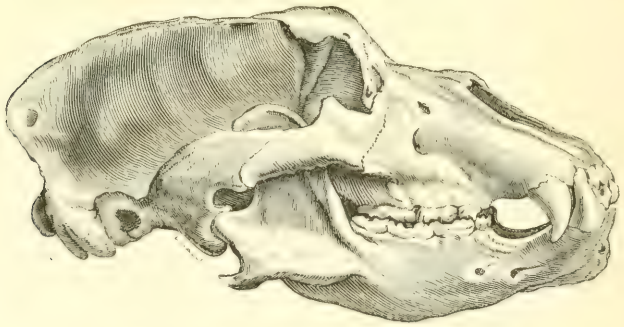


Fig. 674.—Skull of *Ursus spelæus*. Post-Pliocene.

as its name implies, has been found mainly in cavern-deposits. The size of this species considerably exceeded that of any existing Bear, and it is especially characteristic of the later portion of the Post-Pliocene period.

More or less nearly allied to the true Bears are the little living animals which are known as Coatis (*Nasua*), Racoons (*Procyon*), and Kinkajous (*Cercoleptes*), all of which at the present day are confined to the American continent. The *Leptarchus* of the Pliocene of North America is the oldest Ursine type known in this continent, and seems to be allied

to the Coatis. The bone-caves of Brazil have yielded remains of two species of *Nasua*, and a Racoon has been found in Post-Tertiary deposits in Illinois. No certain remains of *Cercoleptes* are known; but the *Arctocyon primævus* of the Eocene Tertiary of France has been compared with the existing Kinkajous.

The only remaining family of the *Plantigrada* is that of the *Melidæ* or Badgers, characterised by their elongated bodies and short legs, and by the fact that the carnassial tooth has a partly cutting edge, and is not wholly tuberculate as in the Bears.

The earliest remains of *Melidæ* are from the Upper Miocene deposits of the Siwâlik Hills in India, in which we meet with the living genus *Mellivora* (comprising the Honey-badgers), and the allied but extinct *Ursitaxus*.

Remains of Badgers have been found in Post-Tertiary deposits in Europe, and they are probably referable to the existing *Meles taxus*. The Gluttons (*Gulo*) are also only known from Post-Tertiary accumulations, and the so-called *Gulo spelæus* of the cavern-deposits of Europe does not appear to be separable from the common Wolverine (*Gulo luscus*).

Section III. Digitigrada.—In this section of the *Carnivora* the heel is raised above the ground, with the whole or the greater part of the metacarpus, so that the animals walk more or less completely on the tips of the toes (fig. 673, c). No absolute line, however, of demarcation can be drawn between the Plantigrade and Digitigrade sections of the *Carnivora*, since many forms (*e. g.*, *Mustelidæ* and *Viverridæ*) exhibit transitional characters, and it has even been proposed to place these in a separate section, under the name of *Semiplantigrada*.

The first family of the *Digitigrada* is that of the *Mustelidæ*, or Weasels and Otters, including a number of small Carnivores, with short legs, elongated worm-like bodies, and a peculiar gliding mode of progression (hence the name of *Vermiformes*, sometimes applied to the group).

The *Mustelidæ* appear for the first time during the Miocene period, at which time there existed in the Old World a considerable number of types referable to this family. Thus in

the Miocene Tertiary of Western Europe, we meet with species of the existing genera *Mustela* (Weasels) and *Lutra* (Otters), together with the extinct *Promephitis* and *Palæomephitis*, and the Otter-like *Potamotherium*. In the same deposits are found the transitional types *Lutrictis* and *Taxodon*; the former intermediate between the Martens and the Civets, with affinities to the Otters; while the latter has relationships with both the Otters and the Badgers. Lastly, in the Upper Miocene of the Siwâlik Hills in India we have species of Otter (*Lutra*), and the related but extinct genus *Enhydriodon*.

The second family of the Semi-plantigrade Carnivores is that of the *Viverridæ*, the Civets and Genettes. They are all of moderate size, with sharp muzzles and long tails, and more or less striped, or banded, or spotted. The carnassial molar is trenchant; the canines are long, sharp, and pointed; and the tongue is roughened by numerous prickly papillæ. The last two upper molars and the last lower molar are tubercular. The claws are semi-retractile, and the pupils can contract, on exposure to light, till they resemble a mere line.

The *Viverridæ* appear to commence in the Eocene Tertiary, being represented in deposits of this age in Europe by the genera *Tylodon* and *Palæonyctis*, and in North America by *Viverravus*. In the Lower Miocene of Europe occurs the extinct genus *Proviverra*; and the researches of Gaudry have thrown an interesting light upon the Viverrine *Ictitherium*, from the Upper Miocene deposits of Attica. In this genus, though the upper jaw resembles that of the true Civets in possessing two tubercular molars behind the carnassial (fig. 675), the hindmost of these is of small size, and sometimes almost rudimentary, thus approximating to the type of the Hyænas, in which this tooth is altogether wanting. The hind-feet, further, have only four toes. Of later forms, we may note the *Galecynus* of the Pliocene of Œningen, in Switzerland, which seems to be intermediate between the Civets and the Dogs.

Forming a transition between the *Viverridæ* and the *Felidæ* is the family of the *Hyænidæ*, distinguished by the fact that,

alone of all the *Carnivora*, both pairs of feet have only four toes each. The hind-legs are shorter than the fore-legs, so that the trunk sinks towards the hind-quarters, and the tail is short. The tongue is rough and prickly. The head is

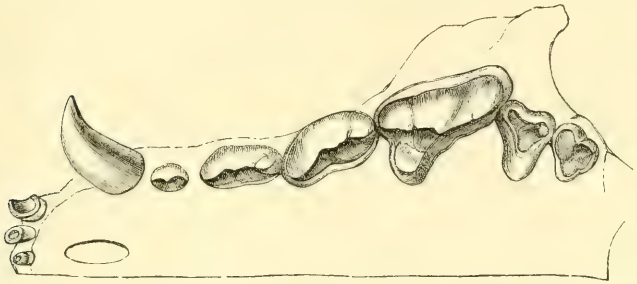


Fig. 675.—Teeth of the left side of the upper jaw of *Ictitherium robustum*, viewed from below, of the natural size. Upper Miocene, Attica. (After Gaudry.)

extremely broad, the muzzle rounded, and the muscles of the jaw extremely powerful and well developed. The claws are non-retractile. All the molars are trenchant except the last upper molar, which is tuberculate. The upper carnassial has a small internal tubercle, and the lower carnassial is wholly trenchant.

The earliest Hyænas appear in the Upper Miocene deposits of the Siwâlik Hills and of Europe, in which occur the

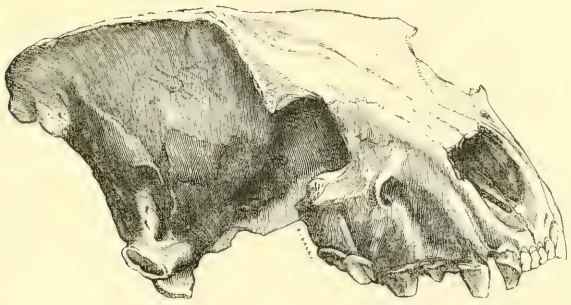


Fig. 676.—Skull of *Hyæna spelæa*. Post-Pliocene.

remains of the genus *Hyæna* itself. In the Upper Miocene of Greece are found the two extinct genera *Hyænictis* and *Lycæna*, the former with affinities to the *Viverridæ*. In the

Pliocene period the genus *Hyæna* was well represented in Europe, the best known species being the *H. hipparionum* of France. Of the Post-Tertiary Hyænas, the best known and most important is the great Cave-hyæna (*Hyæna spelæa*, fig. 676). This species in many respects resembles the *Hyæna crocuta* of South Africa, of which it is probably only a variety; and it inhabited Britain and the greater part of Europe during the Post-Pliocene period. Its remains often occur in great abundance, and no doubt can be entertained as to its having survived into the human period.

The next family is that of the *Canidæ*, comprising the Dogs, Wolves, Foxes, and Jackals. The members of this family are characterised by having pointed muzzles, smooth tongues, and non-retractile claws. The fore-feet have five toes each, the hind-feet have only four. The molar teeth are $\frac{6—6}{7—7}$, sometimes $\frac{7—7}{7—7}$, and of these, two or three on each side are tuberculate. The carnassial has a tolerably large heel or process.

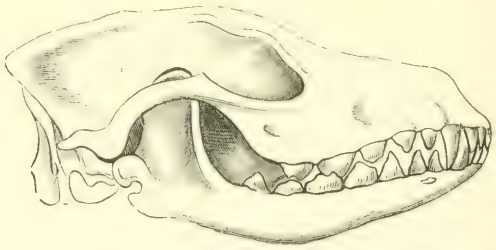


Fig. 677.—Skull of Jackal (*Canis aureus*).

The true Dogs and the Wolves, forming the genus *Canis*, and the Foxes (*Vulpes*), can hardly be distinguished from one another, as fossils, with any certainty. The oldest known types of the *Canidæ* appear in the Eocene of Europe and North America, though the true position of most of these early forms is somewhat uncertain. The *Vulpavus* of North America seems to be related to the living Foxes (*Vulpes*); and the European Eocene has yielded various extinct genera, such as *Galethylax*, *Cynotherium*, and *Cynodon*, which are

probably referable to the *Canidæ*. *Cynodon* (fig. 678) seems to be intermediate between the *Canidæ* and the *Viverridæ*,

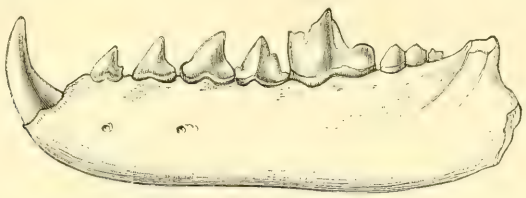


Fig. 678.—Left ramus of the lower jaw of *Cynodon lacustris*, of the natural size. Eocene, France. (Altered from Gaudry.)

agreeing with the former in having two tubercular molars behind the carnassial on each side of the lower jaw, while it approaches the Civets in having an internal process to the lower carnassial. We may also provisionally place in the *Canidæ* the curious *Arctocyon* of the Eocene Tertiary of France, though it is a very generalised type, and possesses peculiarities which prevent it being definitely placed in any family of the existing Carnivores.

In the Miocene Tertiary we meet with a number of types of this family, including the existing genus *Canis*, which has been detected in deposits of this age in North America. Of other Miocene forms, *Pseudocyon* seems to be allied to the Dogs; *Hemicyon* is in some respects intermediate between *Canis* and *Gulo*; and *Simocyon*, of the Upper Miocene of Greece, is an aberrant type, with molars like those of the Dogs, and canines resembling those of the *Felidæ*. The most important of the Miocene *Canidæ*, however, is *Amphicyon*, species of which have been found in Europe, India, and North America. In many of its characters this genus is generalised, since its hind-feet were pentadactylous—those of the Dogs being four-toed—and its mode of progression seems to have been plantigrade, as in the Bears. There existed also an additional molar on each side of the upper jaw, and all the molars were tuberculate. The dentition was therefore complete, the dental formula being—

$$i\ \frac{3—3}{3—3};\ c\ \frac{1—1}{1—1};\ pm\ \frac{4—4}{4—4};\ m\ \frac{3—3}{3—3} = 44.$$

In the true Dogs, on the other hand, an upper molar is missing, and there are thus only two tubercular teeth behind the upper carnassial (the fourth præmolar); the dental formula being—

$$i\ \frac{3—3}{3—3};\ c\ \frac{1—1}{1—1};\ pm\ \frac{4—4}{4—4};\ m\ \frac{2—2}{3—3} = 42.$$

In the Pliocene period, especially in North America, species of *Canis* seem to have abounded, and the same is true of the Post-Pliocene, some of the Post-Tertiary forms being nearly or quite inseparable from existing species. Thus, the so-called *Canis familiaris fossilis* of the caves of Germany, Belgium, and France, appears to be very nearly allied to the domestic Dog of the present day. Similarly, the so-called *Canis spelæus*, and *Canis vulpes spelæus* are nearly, if not quite, identical with the existing Wolf and Fox of Europe.

We may here intercalate the singular extinct genus *Hyænodon*, with its allies, for which it is necessary to establish the distinct family of the *Hyænodontidæ*. *Hyænodon* is found in the Eocene and Miocene Tertiary of Europe, and in deposits of the latter age in North America, and is remarkable on account of the nature of its teeth. The dentition is complete, the dental formula being—

$$i\ \frac{3—3}{3—3};\ c\ \frac{1—1}{1—1};\ pm\ \frac{4—4}{4—4};\ m\ \frac{3—3}{3—3} = 44.$$

Moreover, there is the character—unexampled among the existing Carnivores — that *all* the molars have trenchant edges, and are of the "carnassial" or sectorial form; and there are no "tubercular" molars (fig. 679). In this respect *Hyænodon* approximates to the living Marsupial genus *Thylacinus*. The extinct genus *Pterodon* of the European Eocene is nearly allied to *Hyænodon*, as is also the *Dromocyon* of the Middle Eocene of North America. The latter, however, has only four lower incisors. *Mesonyx* and *Limnocyon*, of the American Eocene, also seem to properly find a place in the family of the *Hyænodontidæ*, though the former has some very peculiar characters.

The last group of the *Digitigrada* is that of the *Felidæ*, or

Cat tribe, comprising the most typical members of the whole order of the *Carnivora*, such as the Lions, Tigers, Leopards, Cat, and Panthers. The members of this family all walk upon the tips of their toes, the soles of their feet being hairy,

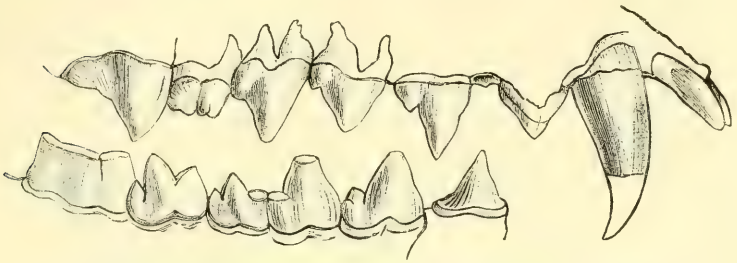


Fig. 679.—Teeth of *Hyænodon horridus*, viewed from one side, reduced in size, the lower canine and incisors being wanting. Miocene Tertiary, North America. (After Leidy.)

and the whole of the metacarpus and heel being raised above the ground (fig. 673, c). The jaws are short, and, owing to this fact, and to the great size of the muscles concerned in mastication, the head assumes a short and rounded form,

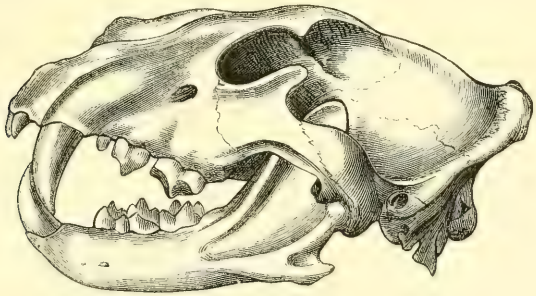


Fig. 680.—Side view of the skull of the Lion (*Felis leo*).

with an abbreviated and rounded muzzle. The molars and præmolars are fewer in number than in any other of the *Carnivora* (hence the shortness of the jaws), and they are all trenchant, except the last molar in the upper jaw, which is tuberculate. The upper carnassial has three lobes, and a blunt heel or internal process. The lower carnassial has two cutting lobes, and no internal process. The dental formula is—

$$i\,\frac{3—3}{3—3};\ c\,\frac{1—1}{1—1};\ pm\,\frac{3—3}{2—2};\ m\,\frac{1—1}{1—1}=30.$$

The legs are nearly of equal size, and the hind-feet have only four toes each, whilst the fore-feet have five. All the toes are furnished with strong, curved, retractile claws, which, when not in use, are withdrawn within sheaths by the action of elastic ligaments, so as not to be unnecessarily blunted.

The earliest known type of the true *Felidæ* would seem to be the *Limnofelis* of the Middle Eocene of North America, which appears to be a genuine Cat, though its structure is not fully known. There are also other Eocene types, which, when fully understood, may prove to be referable to this family. In the Miocene period true *Felidæ* abounded, as also in the Pliocene, both in Europe and North America. In addition to various forms referable to the existing genus *Felis*, the Miocene deposits have yielded the remains of the singular extinct genera *Pseudælurus*, *Dinictis*, and *Machairodus*. The first of these differs from *Felis* proper, in possessing an additional præmolar in the lower jaw, and it is found in the Miocene of Europe and the Pliocene of North America. *Dinictis*, on the other hand, not only has an additional lower præmolar on each side, but it possesses a minute tubercular molar behind the carnassial tooth. It occurs in the Miocene of North America. Lastly, the genus *Machairodus* includes the so-called "sabre-toothed Tigers," and is widely distributed both in space and time, ranging from the Miocene to the close of the Post-Pliocene, and being already known to occur in Britain, in the Continent of Europe, in India, and in North and South America. *Machairodus* presents us with the Carnivorous type in the most specialised condition at present known; the upper canines being extraordinarily developed, trenchant, and sabre-shaped, with finely-serrated margins (fig. 681). No true molar is present in the upper jaw, and the præmolars are reduced to two on each side of each jaw. The dental formula is—

$$i\,\frac{3—3}{3—3};\ c\,\frac{1—1}{1—1};\ pm\,\frac{2—2}{2—2};\ m\,\frac{0—0}{1—1}=26.$$

The Post-Pliocene deposits of the Old and New World contain a great number of *Felidæ*, some belonging to extinct types, but the majority referable to genera now in existence. Of the latter, the most interesting and important form is the great Cave-lion (*Felis spelæa*) of Europe, which does not appear to be separable by any character of importance from

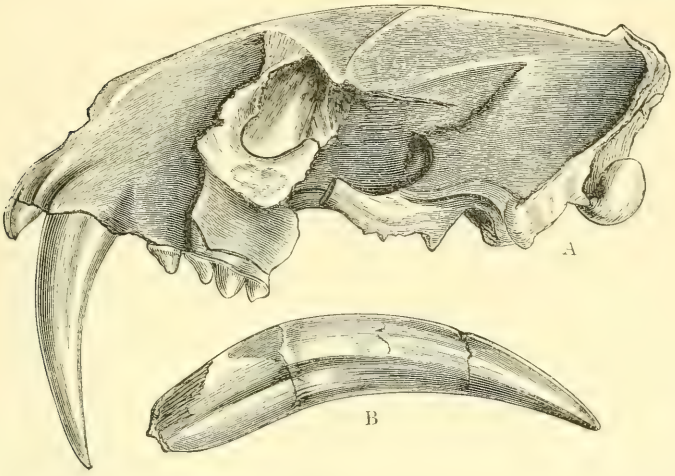


Fig. 681.—A, Skull of *Machairodus cultridens*, without the lower jaw, reduced in size; B, Canine tooth of the same, one-half the natural size. Pliocene, France.

the existing Lion (*Felis leo*). This species inhabited Britain in times subsequent to the Glacial period, and was a contemporary of the Cave-hyæna, Cave-bear, Woolly Rhinoceros, and Mammoth. There can also be no doubt but that the Cave-lion survived into the earlier portion of the human period.

CHAPTER XLVII.

ORDERS OF MAMMALIA (*Continued*).

Rodentia, Cheiroptera, and Insectivora.

Order XIII. Rodentia. — The thirteenth order of *Mammalia* is that of the *Rodentia*, or Rodent Animals, often spoken of as *Glires*, comprising the Mice, Rats, Squirrels, Rabbits, Hares, Beavers, &c.

The *Rodentia* are characterised by the possession of *two long curved incisor teeth in each jaw, separated by a wide interval from the molars. The lower jaw never has more than two of these incisors, and the upper jaw rarely; but sometimes there are four upper incisors. There are no canine teeth, and the molars and præmolars are few in number (rarely more than four on each side of the jaw). The feet are usually furnished with five toes each, all of which are armed with claws; and the hallux, when present, does not differ in form from the other digits.*

The most characteristic point about the Rodents is to be found in the structure of the incisors, which are adapted for continuous gnawing — hence the name of *Rodentia*. The incisor teeth are commonly two in each jaw, and they grow from persistent pulps, so that they continue to grow throughout the life of the animal. They are large, long, and curved (fig. 682, a), and are covered anteriorly by a plate of hard enamel. The back part of each incisor is composed only of the comparatively soft dentine, so that when the tooth is exposed to attrition, the soft dentine behind wears away

more rapidly than the hard enamel in front. The result of this is that the crown of the tooth acquires by use a chisel-like shape, bevelled away behind, and the enamel forms a persistent cutting edge.

The gnawing action of the incisors is assisted by the articulation of the lower jaw, the condyle of which is placed

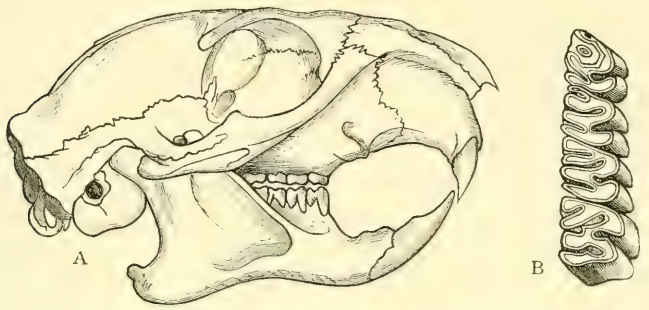


Fig. 682.—A, Side view of the skull of *Sciurus* (*Cynomys*) *Ludovicianus*; B, Molar teeth of the upper jaw of the Beaver (*Castor fiber*). (After Giebel.)

longitudinally and not transversely, so that the jaw slides backwards and forwards. The molars, consequently, have flat crowns (fig 682, B), the enamelled surfaces of which are always arranged in transverse ridges, in opposition to the antero-posterior movements of the jaw.

The Rodents make their first appearance in the Eocene Tertiary, and abound at the present day. Very many fossil forms are known, and many of these, even of the oldest, belong to genera still in existence, though few are of special interest.

The order *Rodentia* comprises a very large number of families, of which only those containing important fossil representatives can be noticed here.

Fam. 1. *Leporidæ.* — In this family are the Hares (*Lepus timidus*) and Rabbits (*Lepus cuniculus*), distinguished amongst the Rodents by the possession of two small incisors in the upper jaw, placed behind the central chisel-shaped incisors, so that there are four upper incisors in all. The molars and præmolars are rootless, and the dental formula is—

$$i\,\frac{2—2}{1—1}\,;\ c\,\frac{0—0}{0—0}\,;\ pm\,\frac{3—3}{2—2}\,;\ m\,\frac{3—3}{3—3}=28.$$

The clavicles are imperfect. The fore-legs are furnished with five toes, and are considerably shorter than the hind-legs, which have only four toes. The two orbits communicate by an aperture in the septum. Generally there is a short erect tail.

The genus *Lepus* itself is found in the Pliocene deposits of both North and South America, and in the Post-Pliocene cave-deposits of Brazil occurs a Hare, nearly allied to the living *L. Brasiliensis*. In the Miocene of North America the Hares are represented by the extinct genus *Palæolagus*, and in the Pliocene of the same country we have the extinct genus *Panolax*. Forms closely allied to, or actually belonging to, the genus *Lepus* have also been indicated as occurring in the Miocene, Pliocene, and Post-Pliocene deposits of Europe.

Fam. 2. *Lagomydæ*.—In the Calling-hares or Pikas (*Lagomys*), which form this family, the legs do not differ much in size, there is no visible tail, and the clavicles are nearly complete. They are found in Russia, Siberia, and North America.

The existing genus *Lagomys* is found as early as the Miocene in France, and occurs also in the Pliocene of Europe, while the Cave-pika is found in the Post-Glacial deposits of Britain. The *Titanomys* of the French Miocene differs from *Lagomys* chiefly in the possession of a lower molar fewer (fig. 683, D). In the neighbourhood of the Hares and Calling-hares we may provisionally place the remarkable and aberrant *Typotherium* (or *Mesotherium*) of the Pliocene of South America, which presents affinities both to the Toxodonts and the Ungulates, and which cannot at present be definitely referred to any family of the Rodents. This singular form was larger than the existing Capybara, and therefore possessed dimensions greater than those of any living Rodent. It had clavicles, and the fore-feet were pentadactylous, while the hind-feet had only four toes. The dental formula is—

$$i\,\frac{1—1}{2—2};\ c\,\frac{0—0}{0—0};\ pm\,\frac{2—2}{1—1};\ m\,\frac{3—3}{3—3}=24.$$

Fam. 3. *Cavidæ.*—In this family are the living Capybaras (*Hydrochærus*), Agoutis (*Dasyprocta*), Pacas (*Cœlogenys*), &c., characterised by their absence of clavicles, their rudimentary tail, their unguiculate toes, and their general possession of eight rootless molars in each jaw (fig. 683). Almost all the existing members of this family belong to South America, and this continent has been peopled during Post-Tertiary times with numerous species more or less nearly allied to living forms. Thus, the Brazilian bone-caves have yielded to the researches of Lund remains of Guinea-pigs (*Anæma*), Agoutis, Pacas, and Capybaras, all of which appear to belong to extinct species. The Capybaras (*Hydrochærus*) seem to have extended their range to North America during the Post-Pliocene period; while Cavies occur in South America as early as the Pliocene. Remains from the Miocene of Europe have also been discovered indicating the past existence of Cavies and Agoutis in this region.

Fam. 4. *Hystricidæ.*—In this family are the well-known Porcupines, distinguished from the other Rodents by the fact that the body is covered with long spines or "quills," mixed with bristly hairs. They have four molars on each side of each jaw, and they possess imperfect clavicles.

The genus *Hystrix* appears first in the Upper Miocene of Europe, in the person of a species nearly allied to the living *H. cristata*, and other forms appear in the Pliocene of the same region. The *H. venustus* of the Pliocene of North America is also related to the *H. cristata* of Southern Europe.

Fam. 5. *Cercolabidæ.*—This family is hardly separable from the preceding, the chief difference being that the animals composing it spend more or less of their lives in trees, and are therefore adapted for climbing. The only fossil form referable to this family is a large *Cercolabes* found in the Post-Pliocene cave-deposits of South America, in which region the genus still survives.

Fam. 6. *Octodontidæ.*—This family includes a large number

of living Rodents which are principally South American and African (*Octodon, Echimys, Ctenomys,* &c.)

The most important extinct type of this family is the *Theridomys* of the Eocene and Miocene of Europe, and of the Eocene of South America (fig. 683, B), which is allied to the living Spiny Rats (*Echimys*), and also has points of relationship with the Beavers. The *Megamys* of the South American Eocene and the *Palæomys* of the Miocene of Europe are, further, believed to be related to the living *Capromys* of the West Indies. Lastly, the genus *Ctenomys* occurs in the Pliocene of South America; and the bone-caves of Brazil have yielded remains of *Echimys,* together with a species of Coypu (*Myopotamus*).

Fam. 7. *Chinchillidæ.*—This family includes some South American Rodents, of which the true Chinchillas (*Chinchilla*) are the best known. They are small nocturnal animals, strictly terrestrial in their habits, and having the hind-legs considerably longer than the fore-legs.

We may, perhaps, place in this family the extinct genus *Archæomys* (fig. 683, A) from the Miocene of France.

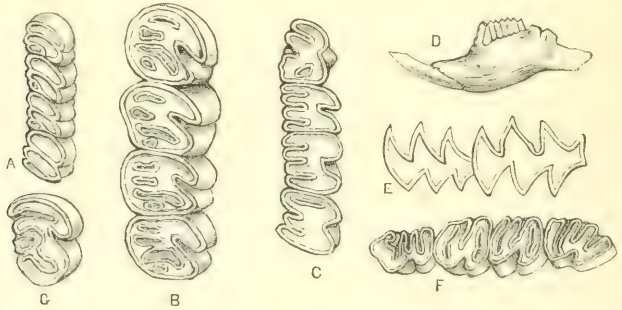


Fig. 683.—A, Lower molars of *Archæomys chinchilloides*—Miocene, France; B, Upper molars of *Theridomys Lembronica*—Miocene, France; C, Lower molars of *Chalicomys Jægeri*—Miocene, Germany; D, Left ramus of lower jaw of *Titanomys Visenoviensis*—Miocene, France; E, Two lower molars of the living Lemming (*Lemmus Norvegicus*); F, Lower molars of the living Paca (*Cœlogenys paca*); G, One of the lower molars of the living Beaver (*Castor fiber*).

Species of Viscacha (*Lagostomus*) have also been found in the Pliocene and Post-Pliocene deposits of South America; and the cave-deposits of Anguilla in the West Indies have yielded the remains of the extinct genera *Amblyrhiza* and *Loxomylus.*

Fam. 8. *Castoridæ.*—The best-known example of this family is the Beaver (*Castor fiber*). The distinctive peculiarities of the family are the presence of distinct clavicles, the possession of five toes to each foot, and the fact that the hind-feet are webbed, adapting the animal to a semi-aquatic life.

A considerable number of fossil *Castoridæ* are known, commencing with the *Stenofiber* of the Miocene of France, and the *Palæocastor* of the Miocene of North America. The genus *Castor* itself is said to occur in the French Miocene, and is certainly present in the Pliocene of Europe. The *Castor spelæus* of the European cave-deposits does not appear to be specifically separable from the existing Beaver (*Castor fiber*). The great *Trogontherium* (fig. 684) of the Post-Tertiary deposits of Europe, also appears to be hardly generically separable from *Castor*. The *Castoroides Ohioensis* of the Post-Tertiary period of North America seems to be rightly referred to a separate genus. The only known species attained a comparatively gigantic size, reaching a length of about five feet. Lastly, the *Chalicomys* of the European Miocene and Pliocene deposits appears to be nearly related to the Beavers, if it be really generically distinct.

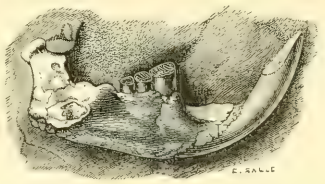


Fig. 684.—Jaw of *Trogontherium Cuvieri*. Post-Pliocene.

Fam. 9. *Muridæ.*—The next family of Rodents is that of the *Muridæ*, comprising the Rats, Mice, and Lemmings. In this family the tail is long, always thinly haired, sometimes naked and scaly. The lower incisors are narrow and pointed, and there are complete clavicles. The hind-feet are furnished with five toes, the fore-feet with four, together with a rudimentary pollex.

The remains of *Muridæ* are abundant in the Tertiary deposits, the oldest being the extinct *Mysops* and *Colonomys* of the Eocene of North America. In the Miocene of France are various species of the extinct genus *Cricetodon*, allied to the living Hamsters (*Cricetus*), together with species of

Myarion, supposed to be nearly allied to the existing *Hesperomys* of North America.

The genus *Cricetus*, comprising the existing Hamster, is known to occur in the Pliocene deposits of Europe, and is represented in Post-Tertiary deposits by a form probably identical with the living *C. vulgaris*. The Lemmings (*Myodes*) are represented by at least one species in Post-Tertiary deposits in Britain, occurring after the Glacial period, and being contemporary with "palæolithic" man. The Voles or Campagnols (*Arvicola*) commence in the Pliocene, and are abundantly represented in Post-Tertiary deposits. The Post-Glacial deposits of Britain have yielded remains of the *Arvicola pratensis*, *A. agrestis*, and *A. amphibia*, the last of which (the well-known "Water-rat") occurs also in Præ-Glacial accumulations.

Fam. 10. *Dipodidæ*.—The next family of the Rodents, which is sufficiently important to need notice, is that of the *Dipodidæ* or Jerboas, mainly characterised by the disproportionate length of the hind-limbs as compared with the fore-limbs. The tail also is long and hairy, and there are complete clavicles.

The genus *Dipus* itself is stated to occur in the Miocene Tertiary of Europe; and the French Pliocene has yielded remains of the extinct genus *Issiodromys*, supposed to be allied to the existing Jumping Hares (*Pedetes*) of Southern Africa.

Fam. 11. *Myoxidæ*.—The members of this family are commonly known as Dormice, and they are often included in the following family of the Squirrels and Marmots.

They resemble the Squirrels in most respects, but they have only four molars on each side of the upper jaw, whereas the latter possess five. Two species of *Myoxus* have been detected in the Upper Eocene (Gypseous series of Montmartre), and a third species has been determined from beds of Miocene age. Several species have been detected in Post-Tertiary deposits, of which the most remarkable is the comparatively gigantic *Myoxus Melitensis* of the Maltese Post-Pliocene. This form is described by Falconer as being "as big in comparison to the living Dormouse as the Bandicoot-rat to a Mouse."

Fam. 12. *Sciuridæ.*—This is the last family of Rodents which calls for any special mention, and it comprises the true Squirrels, the Flying Squirrels, and the Marmots.

The members of this family are distinguished by their pointed or compressed incisors and their tubercular molars, the upper jaw having five of the latter on each side, whilst the lower jaw has only four. The genus *Sciurus*, comprising the true Squirrels, is represented from the Eocene Tertiary upwards, but none of the fossil forms are of special interest. *Sciuravus* and *Paramys* appear to represent the true Squirrels in the Eocene of North America, as does *Ischyromys* in the Miocene Tertiary of the same region; while the *Allomys* of the American Miocene may perhaps be related to the Flying Squirrels. The earliest form representative of the existing Marmots (*Arctomys*) seems to be the *Plesiarctomys* of the Eocene of France, which has relations to the Squirrels. *Arctomys* itself does not appear till the Miocene is reached; and there are several Post-Tertiary forms. Lastly, the Pouched Marmots (*Spermophilus*) appear for the first time in the Miocene; and Britain possessed two species in times posterior to the Glacial period.

Order XIV. Cheiroptera.[1]—This order is, from one point of view, "the most distinctly circumscribed and natural group" in the whole class of the *Mammalia*. In many respects, however, it would be advantageous to regard the *Cheiroptera* as a sub-order of the next order (namely, the *Insectivora*) specially modified to lead an aerial life; just as the *Pinnigrada* are regarded as a mere section of the *Carnivora* specially modified to suit an aquatic life.

The *Cheiroptera* are essentially characterised by the fact that *the anterior limbs are longer than the posterior, the digits of the fore-limb, with the exception of the pollex, being enormously elongated* (fig. 685). *These elongated fingers are united by an expanded membrane or "patagium," which is also extended between the fore and hind limbs and the sides of the body, and in many cases passes also between the hind-limbs and the tail. The patagium thus formed is naked, or nearly so, on*

[1] The *Cheiroptera* were placed by Linnæus in his order *Primates*, which contained also the Lemurs, the Apes, and Man.

both sides, and it serves for flight. Of the fingers of the hand, the poller, and sometimes the next finger as well, is unguiculate, or furnished with a claw; but the other digits are destitute of nails. In the hind-limbs all the toes are unguiculate, and the hallux is not in any respect different from the other digits. Well-developed clavicles are always present, and the radius has no power of rotation upon the ulna. The mammary glands are two in number, and are placed upon the chest. There are teeth of three kinds, and the canines are always well developed. The molars are tuberculate or grooved in the frugivorous forms, and cuspidate in the insectivorous species. The ulna is sometimes quite rudimentary. The bones are not pneumatic.

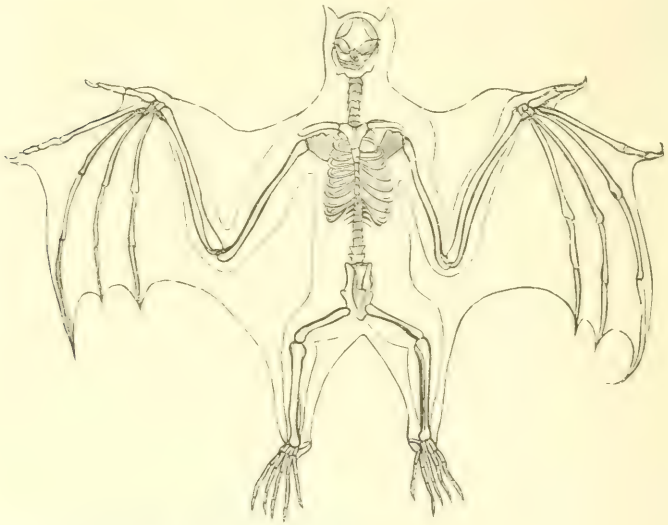


Fig. 685.—Skeleton of Fox-bat (*Pteropus*). (After Owen.)

The living Bats are divided into the two groups of the Frugivorous Bats, comprising the single family of the *Pteropida* (Fox-bats or Roussettes), and the Insectivorous Bats, comprising the three principal families of the *Vespertilionida*, the *Rhinolophida* (Horse-shoe Bats), and the *Phyllostomida* (Vampire Bats). The *Cheiroptera* are represented in Europe for the first time in the Eocene Tertiary, and that by a form very similar to the existing European Bats. The fossil in question

is the *Vespertilio Parisiensis* (fig. 686) of the Gypseous series of Montmartre (Upper Eocene). A species of Horse-shoe Bat (*Rhinolophus*) is found at a lower horizon. Other species of

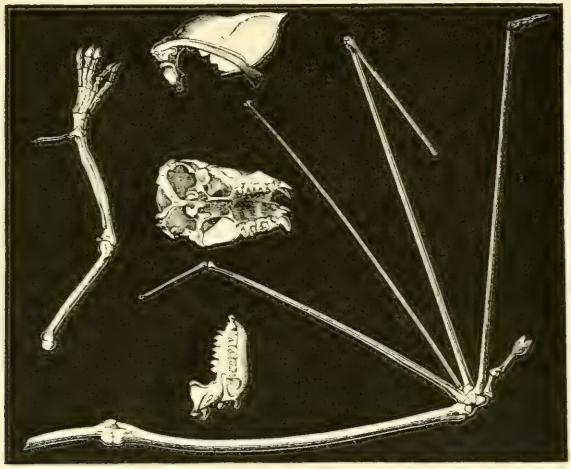


Fig. 686.—*Vespertilio Parisiensis.* Upper Eocene.

Insectivorous Bats, referable to the extinct genera *Nyctilestes* and *Nyctitherium*, are found in the Middle Eocene of North America. In the Post-Tertiary of Europe and North America are found various remains of Bats, but all of existing types.

Lastly, the Vampire Bats are represented by no less than five species in the Post-Pliocene cave-deposits of Brazil, in which country is found the living *Phyllostoma spectrum*.

Order XV. Insectivora.—The fifteenth order of Mammals is that of the *Insectivora*, comprising a number of small Mammals which are very similar to the Rodents in many respects, but want the peculiar incisors of that order, and are likewise always furnished with clavicles.

In the *Insectivora all the three kinds of teeth are usually present, but the exact nature of the dentition varies considerably in different cases. The incisors and canines present little special, but the molars* (fig. 687) *are always serrated with numerous small pointed eminences or cusps, adapted for crushing insects. With one exception, clavicles are always present in a complete form. All the feet are usually furnished with five toes; all the*

toes are furnished with claws; and the animal walks on the soles of the feet, or is plantigrade. They are mostly nocturnal and subterranean, and generally hibernate. They are all of small size, and are found everywhere, except in the continents of South America and Australia, where their place is filled by Marsupials.

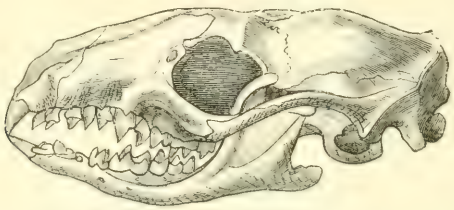


Fig. 687.—Side view of the skull of the Hedgehog (*Erinaceus Europæus*).

Of the numerous existing families of the *Insectivora*, the only ones which can be said with any certainty to be represented in the fossil state are the Moles (*Talpidæ*), the Hedgehogs (*Erinaceidæ*), and the Shrew-mice (*Soricidæ*); and these are at the same time the leading families of the order. The two first of these appear to be represented as early as the Eocene Tertiary, and the third appears in the Miocene; but none of the fossil forms are of special importance, nor do they differ conspicuously from existing forms.

Fam. 1. *Talpidæ.*—The body in this family is covered with hair; the feet are formed for digging and burrowing, and the toes are furnished with strong curved claws.

The earliest remains of Moles appear in the Eocene of North America, where we have the extinct genus *Talpavus*. The *Herpetotherium* of the Miocene of the same region seems to be likewise related to the Moles. In the Miocene of France and Germany occur various mole-like animals, which have been referred to extinct genera (*Dimylus, Geotrypus*, &c.) The extinct genus *Palæospalax* occurs in the Pliocene of Belgium; and the common Mole (*Talpa Europæa*) occurs in the Post-Pliocene deposits of Britain and the Continent. Indeed, the genus *Talpa* is said to occur in France in sediments as old as the Miocene.

Fam. 2. *Soricidæ.*—The *Soricidæ* or Shrew-mice are dis-

tinguished by having the body covered with hair, and the feet not adapted for digging; whilst there are external ears, and the eyes are well developed. Of all the *Insectivora*, no division is more abundant or more widely distributed than that of the Shrew-mice. In general form and appearance the Shrews very closely resemble the true Mice (*Muridæ*) and the Dormice (*Myoxidæ*), but they are in reality widely different, and must not be confounded with them.

Remains of Shrews (belonging to the genera *Sorex*, *Mysarachne*, and *Plesiosorex*, fig. 688) have been discovered in the Miocene deposits of Europe. In the Miocene of North America, the genus *Embasis* appears to be related to the Shrews. Several existing species (such as *Sorex arancus* and *S. fodiens*) occur in Post-Tertiary cave-deposits and ossiferous breccias. Lastly, the Desmans (*Myogale*) are represented from the Miocene Tertiary onwards.

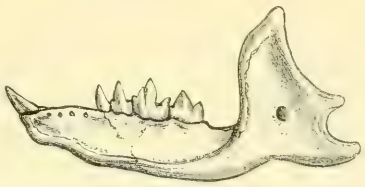


Fig 688.—Left ramus of lower jaw of *Plesiosorex soricinoides*, twice the natural size. Miocene, France. (After Pomel.)

Fam. 3. *Erinaceidæ*.—The last family of the *Insectivora* is that of the Hedgehogs, characterised by the fact that the upper part of the body is covered with prickly spines, the feet are not adapted for digging, and the animal has mostly the power of rolling itself into a ball at the approach of danger.

The genus *Anomys* of the Eocene of North America appears to be a member of this family, and if so is its oldest known representative; while the *Esthonyx* of the same formation may possibly belong here. True Hedgehogs appear for the first time in Europe in the Miocene Tertiary, some of the species belonging to *Erinaceus* itself, while others have been referred to nearly allied but extinct genera (*Amphechinus*, &c.) In the later Tertiary and Post-Tertiary of Europe, remains of Hedgehogs are not uncommon, and the *Erinaceus fossilis* of the Post-Pliocene, does not appear to be separable from the common Hedgehog (*E. Europæus*).

CHAPTER XLVIII.

ORDERS OF MAMMALIA (*Concluded*).

Quadrumana and Bimana.

Order XVI. Quadrumana.—The sixteenth order of Mammals is that of the *Quadrumana*, comprising the Apes, Monkeys, Baboons, Lemurs, &c., characterised by the following points:—

The hallux (*innermost toe of the hind-limb*) *is separated from the other toes, and is opposable to them, so that the hind-feet become prehensile hands. The pollex* (*innermost toe of the fore-limbs*) *may be wanting, but when present, it also is usually opposable to the other digits, so that the animal becomes truly quadrumanous, or four-handed.*

The incisor teeth generally are $\frac{2—2}{2—2}$, *and the molars* $\frac{3—3}{3—3}$, *with broad and tuberculate crowns. Perfect clavicles are present. The teats are two in number, and* (*except in Cheiromys*) *are pectoral in position, and the placenta is discoidal and deciduate.*

The *Quadrumana* are divided by Owen into three very natural groups, separated from one another by their anatomical characters and by their geographical distribution as follows:—

Strepsirhina.

This section of the *Quadrumana* is characterised by the possession of twisted or curved nostrils, placed at the end of

the snout. The incisor teeth are generally much modified, and are in number $\frac{3—3}{3—3}$ as a rule; the lower incisors are produced and slanting; the præmolars are $\frac{3—3}{3—3}$ or $\frac{2—2}{2—2}$, and the molars are tuberculate (fig. 689). The second digit of the hind-limb has a claw, and both fore and hind feet have five toes each, all the thumbs being generally opposable. In the true Lemurs, all the digits, except the second toe of the hind-feet, are furnished with nails.

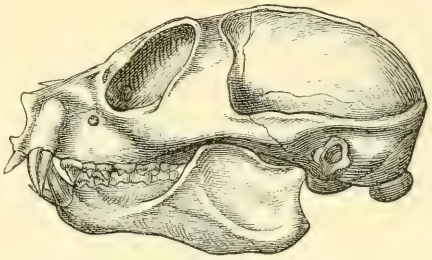


Fig. 689.—Side view of the skull of a living Lemuroid (*Stenops tardigradus*). (After Giebel).

This section is often called that of the *Prosimiæ*, and it includes several families, of which the Aye-ayes, Loris, and true Lemurs are the most important.

Milne-Edwards and Gervais, from an examination of the placentation of the Lemuroids and of their cerebral characters, conclude that the group should be raised to the rank of a distinct order intermediate between the *Carnivora* and the *Quadrumana*.

Until quite recently little or nothing could be said to be known as to the existence in past time of Lemuroid *Quadrumana*. Now, on the other hand, a large number of fossil Lemuroids are known, commencing in the Eocene Tertiary; though as regards most of these the available information is still imperfect. In the European area the earliest remains of Strepsirhine Monkeys have been detected in the Eocene, the *Cœnopithecus lemuroides* of Rütimeyer seeming to be a true Lemuroid. The genera named *Adapis* and *Aphelotherium*, of the French Eocene—the former originally referred by Cuvier to the Ungulates—would also appear to be Lemuroids. The *Palæolemur* and *Necrolemur* of the Miocene deposits of France are likewise considered to be

referable to the *Lemuridæ*, the former presenting resemblances to the living Galago.

In the Tertiary rocks of North America the researches of Professor Marsh have brought to light a most interesting series of Lemuroid remains of Eocene age, indicating the existence during the early Tertiary period of a group of forms apparently higher than the existing *Lemuridæ*, but certainly inferior to the Catarhine Monkeys, and exhibiting many generalised characters in their dentition and osteology. The forms in question are divided by Marsh into the two families of the *Lemuravidæ* and *Limnotheridæ*, represented in the lowest Eocene deposits of New Mexico by the type-genera *Lemuravus* and *Limnotherium*. The former of these, according to its discoverer, "appears to have been most nearly allied to the Lemurs, and is the most generalised form of the Primates yet discovered." The brain is nearly smooth and of moderate size, and the conformation of the skeleton is Lemuroid. The most remarkable point about *Lemuravus*, however, is the dentition, there being the complete series of forty-four teeth present, and the dental formula being—

$$i\,\frac{3—3}{3—3};\ c\,\frac{1—1}{1—1};\ pm\,\frac{4—4}{4—4};\ m\,\frac{3—3}{3—3}=44.$$

The genus *Hyopsodus* appears to be nearly related to *Lemuravus*.

The genus *Limnotherium*—the type of the *Limnotheridæ*—is also "nearly related to the Lemurs, but shows some affinities to the South American Marmosets." There were only forty teeth, the dental formula being—

$$i\,\frac{2—2}{2—2};\ c\,\frac{1—1}{1—1};\ pm\,\frac{4—4}{4—4};\ m\,\frac{3—3}{3—3}=40.$$

"The brain was nearly smooth, and the cerebellum large, and placed mainly behind the cerebrum. The orbits are open behind, and the lachrymal foramen is outside the orbit" (Marsh). Various other genera from the Eocene rocks (*Thinolestes*, *Telmatolestes*, *Microsyops*, &c.) are placed by Marsh in the family of the *Limnotheridæ*. In the Miocene

deposits of North America is found the genus *Laopithecus*, which is stated to have relationships both with the *Limnotheridæ* and with some of the Platyrhine Monkeys of South America.

Platyrhina.

The section of the Platyrhine Monkeys is exclusively confined to South America, and one of its leading characters is to be found in the almost universal possession of a prehensile tail; this being an adaptive character by which the animal is suited to the arboreal life which so many of the South American Mammals are forced to lead. There are neither cheek-pouches nor natal callosities, and there is an additional præmolar, and sometimes a molar less than in Man and the Old World Monkeys. The nostrils are simple, wide apart, and placed nearly at the extremity of the snout. The præmolars are $\frac{3—3}{3—3}$ in number, and have blunt tubercles. The thumbs of the fore-hands are either wanting altogether, or, if present, are not opposable, though versatile.

The fossil remains of Platyrhine Monkeys are only known to occur in South America, to which country all the existing forms are confined. Here, in deposits of late Tertiary or Post-Tertiary age, have been found remains of Monkeys referable to the existing genera *Cebus*, *Callithrix*, and *Iacchus*, along with a large form which constitutes the extinct genus *Protopithecus*, and which is allied to the recent *Mycetes*. No remains of Platyrhines have hitherto been found in South America in deposits older than the Post-Pliocene, nor in any other country in deposits of Tertiary age. It is possible, however, that the *Laopithecus* of the North American Miocene, above referred to, may be referable to the *Platyrhina* rather than to the *Strepsirhina*.

Catarhina.

The third and highest section of the *Quadrumana* is that of the *Catarhina* or Old World Monkeys. In this section the nostrils are oblique, and are placed close together, and

the septum narium is narrow. The thumbs of all the feet are opposable, so that the animal is strictly quadrumanous. In *Colobus* alone the anterior thumbs (pollex) are wanting. The dental formula is the same as in man, viz.—

$$i\,\frac{2—2}{2—2};\ c\,\frac{1—1}{1—1};\ pm\,\frac{2—2}{2—2};\ m\,\frac{3—3}{3—3}=32.$$

The incisors, however, are projecting and prominent, and the canines—especially in the males—are large and pointed. Moreover, the teeth form an uneven series, interrupted by a diastema or interval. The tail is never prehensile, and is sometimes absent. Cheek-pouches are often present, and the skin covering the *tubera ischii* is almost always callous and destitute of hair, constituting the so-called "natal callosities." With the single exception of a monkey which inhabits the Rock of Gibraltar, all the *Catarhina* are natives of Africa and Asia.

The earliest traces of the Catarhine Monkeys appear in the Miocene Tertiary; and they occur only in the Old World, so far as is yet known. In the Miocene deposits of France and Italy occur the remains of various genera which are referable to the Catarhines. Of these, the genus *Pliopithecus* (fig. 690) appears to have relationships both with the living *Semnopithecus* and the Anthropoid Apes, but its precise position among the Catarhines is uncertain. The *Dryopithecus*, of the Miocene of France, was an Anthropoid Ape of large size, possessing large and pointed canine teeth, and apparently closely related to the existing Gibbons (*Hylobates*). It must therefore have been destitute of cheek-pouches, and its tail must have been rudimentary.

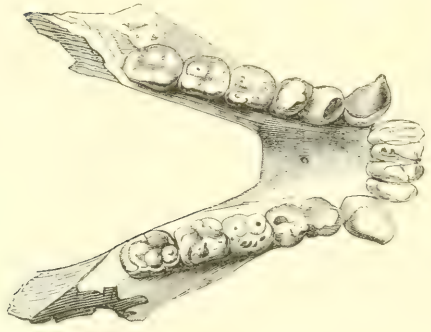


Fig. 690.—Lower jaw of *Pliopithecus* (*Pithecus*) *antiquus*. Miocene.

The *Oreopithecus* of the Italian Miocene is another ancient Catarhine, with some points of affinity to some of the generalised types of the primitive Ungulates in the structure of its teeth. The Upper Miocene of Greece, again, has yielded the remains of an interesting Monkey, to which Gaudry has given the name of *Mesopithecus Pentelici*. In its cranial characters this genus resembles the living *Semnopithecus* of Asia, but the structure of the limbs is similar to that of the Macaques (*Macacus*). The remaining members of the fossil *Catarhina* belong to genera which still survive. Thus the Asiatic genus *Semnopithecus* is found in the Upper Miocene deposits of the Siwâlik Hills in India, and in the Pliocene of France and Italy. The Asiatic and African genus *Macacus* occurs in the Upper Miocene of the Siwâlik Hills, and in the Pliocene of Italy and of the South of England. Lastly, the African genus *Cercopithecus* is found in the Pliocene deposits of France.

Order XVII. Bimana.—This, the last remaining order of the *Mammalia*, comprises Man (*Homo*) alone, and it will therefore require but little notice here, the peculiarities of Man's mental and physical structure properly belonging to other branches of science.

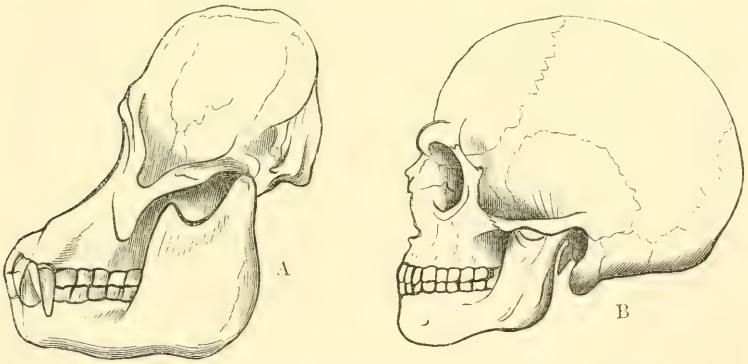


Fig. 691.—A, Skull of the Orang-outang; B, Skull of an adult European.

Zoologically, Man is distinguished from all other Mammals by his habitually erect posture and bipedal progression. The lower limbs are exclusively devoted to progression and to

supporting the weight of the body. The anterior limbs are shorter than the posterior, and have nothing whatever to do with progression. The thumb is opposable, and the hands are prehensile, the fingers being provided with nails. The toes of the hind-limb are also furnished with nails, but the *hallux* is not opposable to the other digits, and the feet are therefore useless as organs of prehension. The foot is broad and plantigrade, and the whole sole is applied to the ground in walking.

The dentition consists of thirty-two teeth, and these form a nearly even and uninterrupted series, without any interval or diastema. The dental formula is—

$$i\,\frac{2—2}{2—2};\ c\,\frac{1—1}{1—1};\ pm\,\frac{2—2}{2—2};\ m\,\frac{3—3}{3—3}=32.$$

The brain is more largely developed and more abundantly furnished with large and deep convolutions than is the case with any other Mammal.

Palæontologically, there is little to be said about Man—or rather, so much might be said on this subject that its discussion can only be properly taken up in a special treatise. Man appeared upon the earth, so far as we know for certain, only in the last or Post-Tertiary period of Geology, and his remains, in the form of bones or implements of various kinds, have been detected in various Post-Tertiary accumulations, such as valley-gravels and cave-deposits. The chief facts as to the past existence of man which concern the palæontological student may be briefly stated as follows:—

1. Man unquestionably existed during the later portion of what Sir Charles Lyell has termed the "Post-Pliocene" period. In other words, Man's existence dates back to a time when several remarkable Mammals, to be afterwards mentioned, had not yet become extinct; but he does not date back to a time anterior to the present *Molluscan* fauna. It should be added, however, that there is some evidence—the value of which cannot be at present accurately appraised — which would go to show that man existed in the later portion of the Tertiary period, in the Pliocene, or possibly even in the Miocene, age. If this were established, then Man, as

a zoological species, would possess an antiquity considerably greater than that of many of the higher Mollusca.

2. The antiquity of the so-called Post-Pliocene period is a matter which must be mainly settled by the evidence of Geology proper, and need not be discussed here.

3. The extinct Mammals with which man coexisted in Western Europe are mostly of large size, the most important being the Mammoth (*Elephas primigenius*), the Woolly Rhinoceros (*Rhinoceros tichorinus*), the Cave-lion (*Felis spelæa*), the Cave-hyæna (*Hyæna spelæa*), and the Cave-bear (*Ursus spelæus*). We do not know the causes which led to the extinction of these Post-Pliocene Mammals; but we know that no Mammalian species has become extinct during the historical period.

4. The extinct Mammals with which man coexisted are referable in many cases to species which presumably required a very different climate to that now prevailing in Western Europe. How long a period, however, has been consumed in the bringing about of the climatic changes thus indicated, we have no means of calculating with any approach to accuracy.

5. Some of the deposits in which the remains of man have been found associated with the bones of extinct Mammals, are such as to show incontestably that great changes in the physical geography and surface-configuration of Western Europe have taken place since the period of their accumulation. We have, however, no means at present of judging of the lapse of time thus indicated except by analogies and comparisons which may be disputed; though the general conclusion that it was a very long and extended one may be safely accepted.

6. The human implements which are associated with the remains of extinct Mammals, themselves bear evidence of an exceedingly barbarous condition of the human species. Post-Pliocene or "Palæolithic" Man was clearly unacquainted with the use of any of the metals. Not only so, but the workmanship of these ancient races was much inferior to that of the later tribes, who were also ignorant of the metals, and who also used nothing but weapons and tools of stone.

7. Lastly, it is only with the human remains of the Post-Pliocene period that the palæontologist proper has to deal. When we enter the "Recent" period, in which the remains of Man are associated with those of *existing species of Mammals*, we pass out of the region of pure palæontology into the domain of the Archæologist and the Ethnologist.

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56. "Description d'un crâne colossal de Dinotherium giganteum." Kaup. 1837.
57. "On the Dentition and Osteology of the Maltese Fossil Elephants." Leith Adams. 'Trans. Zool. Soc. Lond.' 1874.
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PART III.

PALÆOBOTANY

PALÆOBOTANY.

CHAPTER XLIX.

General Relations of Plants to Time.

The subject of Palæobotany or Palæophytology is one which is far too vast to be treated of in a work of this nature; whilst it is one which is of less importance to the general student than that of Palæozoology. For this reason, nothing further will be attempted here than to give the briefest and most elementary outline-sketch of the general distribution of plants in past time, to which will be added a short summary of the chief forms of vegetable life which characterise each of the great formations. The following table shows the leading groups into which the Vegetable Kingdom is divided:—

Divisions of the Vegetable Kingdom.

I. Cryptogamic Plants (Gr. *kruptos*, concealed; *gamos*, marriage), distinguished by having no distinct flowers or fruit. They include—

a. Thallogens.—Ex. Sea-weeds (*Algæ*), Lichens (*Lichenes*), Mushrooms, &c. (*Fungi*).

b. Anogens.—Ex. Liverworts (*Hepaticæ*), Mosses (*Musci*).

c. Acrogens.—Ex. Club-mosses (*Lycopodiaceæ*), Ferns (*Filices*), Horse-tails (*Equisetaceæ*).

II. Phanerogamic Plants (Gr. *phaneros*, conspicuous; *gamos*, marriage), distinguished by having distinct flowers and seeds. They are divided into—

a. Endogens.—*Ex.* Grasses, Palms, Lilies. These have *endogenous* stems, showing no rings of growth, and the young plant possesses but a single seed-lobe or "cotyledon." Hence they are often called *Monocotyledons.*

b. Exogens.—*Ex.* Pines and Cycads, with most ordinary shrubs, trees, and flowering plants. The Pines and Cycads, with the fossil *Sigillariæ*, have the seed naked, and are hence called *Gymnosperms* (Gr. *gumnos*, naked; *sperma*, seed). Ordinary trees and shrubs, on the other hand, have the seed protected by a seed-vessel, and are therefore called *Angiosperms.* Both the Gymnosperms and Angiosperms have an *exogenous* mode of growth, with a true bark and annual rings of growth. The seed also possesses two seed-lobes or "cotyledons;" and they are therefore often spoken of as *Dicotyledons.*

As regards the distribution of the principal groups of the vegetable kingdom in time, the Cryptogams are, on the whole, older than the Phanerogams, though the former are in many instances little adapted for preservation in sedimentary accumulations, and very little is known about the past occurrence of any but the more highly organised sections of flowerless plants. Taking the *Algæ* first, we have but very fragmentary evidence as to the past existence of the microscopic plants which are known as Diatoms and Desmids. The former of these, being furnished with a siliceous epidermis, are quite capable of preservation in the fossil state, but they have, nevertheless, not been as yet detected in any of the older strata of the earth's crust. Recently, Count Castracane announced the discovery of Diatoms in the ashes of coal; but the investigations of Professor Williamson have thrown discredit upon these observations, and we must therefore assume that Diatoms have not hitherto been detected in the Carboniferous rocks. In the Tertiary deposits, however, we meet with great deposits of so-called "Infusorial Earth," which are really in great part made up of the siliceous

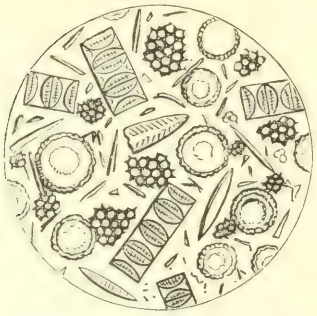

Fig. 602. — Siliceous envelopes of Diatoms, from the "Richmond Earth." Greatly magnified.

envelopes of Diatoms (fig. 692). The most celebrated of these Diatomaceous deposits is the so-called "Richmond Earth" of Virginia, which attains a thickness of thirty feet, and is of Eocene or Miocene age. Another similar deposit is the "tripoli" or "polir-schiefer" of Bohemia. The Desmids, unlike the Diatoms, have no hard covering, and their absence in a fossil state is therefore not surprising. The singular microscopic bodies which are known as "Xanthidia," have, however, been regarded as referable to the *Desmidiæ*. They have the form of minute spheres provided with radiating spines, and they have been detected in the flints of the Chalk, and in the chert of the Devonian formation.

Professor Martin Duncan has recently drawn attention to the existence of minute tubular borings in shells and corals belonging to the Silurian and Devonian periods, which he regards as the work of unicellular filiform parasitic *Algæ*, and which he names *Palæachlya*, on account of their apparent relationship to the recent *Achlya*.

A much more important group of *Algæ* is that represented at the present day by the so-called "Corallines" and "Nullipores." These have the power of secreting calcareous matter within their tissues, and they often attain a considerable size, so that they are well adapted for preservation in the fossil state. Nevertheless, no traces of Nullipores have as yet been determined, with certainty, from the older rocks of the earth's crust. On the other hand, great accumulations of the remains of these stony *Algæ* are found in the Tertiary series of Europe. Thus, the so-called "Leitha-Kalk" of Austria is largely made up of calcareous concretion-like masses, which are undoubtedly referable to the Nullipores (fig. 693). Moreover, if Mr Carter be correct in the view that the singular microscopic bodies known as "coccoliths" are really referable to the Nullipores (*Melobesia*), then we must admit for these singular Algæ a high antiquity; since these structures occur abundantly in chalk, and are stated by Gümbel to be present in almost all limestones, including even those of the Lower Palæozoic formations.

Lastly, the ordinary marine *Algæ* appear to be represented in all the stratified formations, from at least the Lower

Silurian upwards. Many of the more ancient remains which have been set down as "Fucoids" are certainly of a very dubious and indefinite character. Some of them may be inorganic; many are doubtless the work of marine worms;

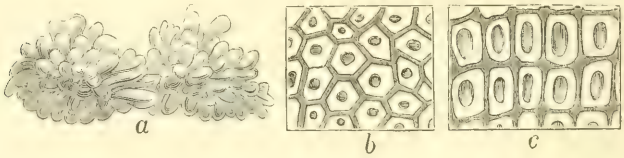

Fig. 693.—*Lithothamnium ramosissimum*, a calcareous Alga, from the "Leitha-Kalk" of the Vienna basin. *a*, Portion of a mass, of the natural size; *b* and *c*, Transverse and vertical sections of the same magnified 320 diameters. (After Gümbel.)

some possibly belong to land-plants; but others may be safely set down as veritable sea-weeds. One of these last, from rocks as old as the Lower Silurian, is here figured; and though it is now so greatly flattened as to be reduced to a

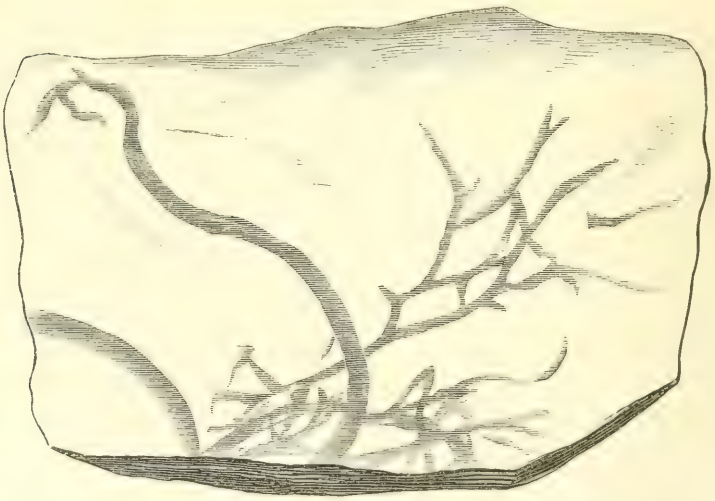

Fig. 694.—*Buthotrephis gracilis*, Hall; a "Fucoid," from the Trenton Limestone of Ottawa. (Original.)

mere impression, its form and its carbonaceous texture leave no room for doubt as to its vegetable nature (fig. 694). An equally unquestionable plant—almost certainly a sea-weed

—is the *Chondrites verisimilis* of the Upper Silurian of Scotland.

The small and peculiar Cryptogamic group of the Charas (*Characeæ*) is known to occur in deposits as old as the Jurassic, by means of their minute spiral seed-vessels or "sporangia," well known under the general name of "gyrogonites."

The great group of the *Fungi* is represented by plants with difficulty susceptible of fossilisation; but we are, nevertheless, able to point to the existence of this section of the Cryptogams in rocks as old as the Carboniferous, owing to the preservation of their mycelium within the woody stem of plants of a higher grade, or from the silicification of the entire fungus. Of the former nature are the mycelial tubules which were detected by Mr Worthington Smith within the axis of a *Lepidodendron*, and which he has named *Peronosporites antiquarius*, in allusion to their remarkable likeness to the Fungus which produces the potato-disease (the *Peronospora infestans*). Of the latter nature are the curious fossils of the Coal-measures of Northumberland, to which Messrs Hancock and Atthey have given the name of *Archagaricon* (fig. 695). These are oval, rounded, lenticular, or irregular bodies, under an inch in length, and composed microscopically of irregular, ramifying, tubular

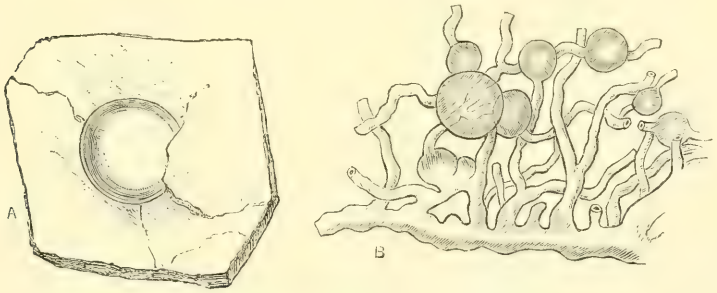

Fig. 695.—A, A lenticular specimen of *Archagaricon*, of the natural size; B, Slice of the same showing the tubes and vesicles, enlarged. Coal-measures. (After Hancock and Atthey.)

filaments, which terminated in rounded vesicles. Goeppert has described a Carboniferous Fungus (*Exstipulites Necsi*), which grows parasitically upon the frond of a fern, and

which has the same carbonaceous texture as the plant to which it is attached. Besides the above-mentioned ancient types, we meet with fossil Fungi in almost all the succeeding great formations, and in the Tertiary period they become comparatively numerous, many forms occurring in amber.[1]

Lichens (*Lichenes*), so far as known, are a modern group of Cryptogams, their first recorded appearance being in the Miocene Tertiary; and the Pillworts (*Rhizocarpeæ*) are hardly more ancient, as they are not known to occur in deposits older than the Eocene.

The three remaining groups of the Cryptogams—namely, the Ferns (*Filices*), the Horse-tails (*Equisetaceæ*), and the Club-mosses (*Lycopodiaceæ*)—all have their beginnings deep down in the Palæozoic period. Ferns seem, according to recent discoveries, to occur at least as early as the middle of the Silurian period (*Eopteris Andegavensis*), and numerous forms, differing in no essential points from those now in existence, were differentiated in the Devonian period. The *Equisetaceæ* are known from Devonian strata, though these ancient types differ in important particulars from the living Horse-tails. Lastly, the *Lycopodiaceæ* appear to begin in the Upper Silurian, with the curious Palæozoic group of the *Lepidodendroids*.

Coming next to the Phanerogams, we find that the group of the Gymnosperms has a decidedly higher antiquity than the Angiosperms (amongst the Dicotyledons), while the latter are a much more modern type than the Monocotyledons. Thus, the Conifers commence in undoubted forms as early as the Devonian; while the Sigillarioids (variously regarded as Cryptogams, or as an ancient type intermediate between Conifers and Cycads) seem to appear as early as the Lower Silurian. The Cycads are doubtfully indicated as occurring in Palæozoic strata, but are represented by unquestionable forms in the Trias. The Angiospermous Dicotyledons, with

[1] Amber is a resinous exudation from the root-stock, bark, and wood of the Miocene *Pinites succinifer*, and probably of other species, more or less related to living *Conifers*. The masses of amber are casts of cavities in the lower part of the stem or root. Amber thus closely resembles the modern "copal" in nature and origin; and its palæontological importance comes from the fact that, besides the remains of plants, it contains an immense number of Insects, Spiders, &c., in a beautiful state of preservation.

dubious exceptions, are not at present known to occur in deposits older than the Upper Cretaceous, and hence would seem to be a modern type. That they are, at any rate, much more modern than the Gymnosperms may be safely concluded, though it may be at the same time taken for granted that we are still very imperfectly acquainted with their geological history, since their first recorded appearance presents us, not merely with a few sporadic precursors of the group, but with a large series of sharply-differentiated and well-known types. Lastly, the Monocotyledons are known to occur as early as the Carboniferous, the *Pothocites* of the Coal-measures being apparently the spadix of a plant allied to the existing Arums.

Taking, in the next place, a brief historical retrospect of the distribution of plants in past time, we find that the oldest remains of vegetables (if truly of this nature) as yet known, are the curious fossils of the Lower Cambrian ("Fucoidal Sandstone") of Sweden, to which the name of *Eophyton* has been given. The precise affinities of *Eophyton* are, however, uncertain, and it cannot even be regarded as being beyond question that it is really referable to the vegetable kingdom. The Lower Silurian rocks, on the other hand, have been long known to yield remains which may be looked upon as incontestably of a vegetable nature, and which are almost certainly Sea-weeds. In addition to these, Professor Lesquereux has recently announced the discovery in strata of this age of fossils which he regards as an early type of the great Palæozoic family of the Sigillarioids (*Protostigma sigillarioides*). In the Upper Silurian have been detected numerous Sea-weeds, and also remains of unquestionable land-plants. Among the latter, the *Lycopodiaceæ* are represented by the singular spore-cases known by the name of *Pachytheca*, by the familiar Palæozoic genus *Lepidodendron*, and by the remarkable generalised type *Psilophyton*, which is in some respects intermediate between the true Club-mosses and the Ferns. Unquestionable Ferns (*Eopteris*), allied to the Devonian and Carboniferous genus *Neuropteris*, are present; and the group of the Calamites among the *Equisetaceæ* is represented by *Sphenophyllum* and *Annularia*.

In the Devonian period—as we now know, from the researches of Dr Dawson of Montreal in particular—plants are very abundant, and belong to varied types. The great group of the Gymnospermous Exogens is here represented by remains of various Conifers (*Dadoxylon*, *Ormoxylon*, and *Prototaxites*). The Ferns are represented by numerous species, in many cases not far removed from types now in existence; and it is interesting to notice that Tree-ferns (*Psaronius* and *Caulopteris*) are not wanting amongst these. The *Lycopodiaceæ* or Club-mosses are represented in the Devonian series by numerous remarkable types, such as *Lepidodendron*, *Lepidophloios*, *Cordaites*, and *Lycopodites*. The Sigillarioid plants, regarded by different authorities as being Coniferous, or Lycopodiaceous, or as being intermediate between the Acrogens and Gymnosperms—are represented by species of *Sigillaria* itself, with its *Stigmaria* roots. The Horse-tails or *Equisetaceæ* are represented by species of the remarkable genus *Calamites*. The genus *Antholithes*, commonly supposed to be the spike of fructification of some phanerogamic plant, and now known to bear the probably Gymnospermous fruit—*Cardiocarpon*—is represented by two species in the Devonian rocks. Lastly, the Devonian formation of the State of New York has yielded the remains of a supposed Angiospermous Exogen, which has been described by Dr Dawson under the name of *Syringoxylon mirabile*.

We thus see, even from such an imperfect summary as the above, that we must abandon the old view that nothing like a general and varied flora existed in times anterior to the Coal-measures. Leaving the imperfectly known floras of the Lower and Upper Silurian, and of the still older Cambrian, on one side, we see that at a point of Palæozoic time as early as that represented by the Devonian formation, the earth exhibited a far from scanty vegetation, composed of true land-plants, and embracing representatives of almost all the great groups of plants which at present grow upon its surface. Thus, we find in the Devonian rocks representatives of the groups of the Horse-tails, Club-mosses, Ferns, and Gymnospermous and Angiospermous Exogens. We have, however, no certain representative of the great group

of the Endogens, whilst the Angiospermous Exogens are doubtfully known by a single genus only, represented by a single species. Upon the whole, therefore, the vegetation of the Devonian period is characterised by the predominance of Cryptogams and Gymnospermous Exogens.

Passing on to the Carboniferous period, we have to consider the largest and most varied of the Palæozoic floras, but one which is in most respects very similar to that of the Devonian period. Some Devonian genera of plants do not pass up into the over-lying formation, and some of the Carboniferous genera have not been recognised in the Devonian; whilst hardly any *species* are common to the two floras. Still, the general *facies* of the Carboniferous vegetation is much the same as that of the Devonian; and the same groups predominate in the former as in the latter. The predominant groups of plants in the Carboniferous rocks are the Ferns (*Filices*), the Sigillarioids, the Lepidodendroids, and the Calamites, of which all except the Sigillarioids are certainly Cryptogams. Here, also, we have the first instance of the occurrence of Fungi (*Archagaricon*, &c.) The *Coniferæ* are well represented by several genera (*Araucarioxylon*, *Dadoxylon*, &c.), but no remains of trees belonging to the Angiospermous Exogens have been as yet detected. There are, however, a few flowering plants (such as the Monocotyledonous *Pothocites* of the Scotch Carboniferous). Lastly, the Carboniferous rocks have yielded remains of the genus *Nœggerathia*, referred by Brongniart to the peculiar Gymnospermous group of the *Cycadaceæ*, but regarded by others as belonging to the Ferns.

In the Permian period, the vegetation is nearly related to that of the Coal-measures. We have still numerous Ferns (*Neuropteris*, *Pecopteris*, *Sphenopteris*), Tree-ferns (*Psaronius*), the Lycopodiaceous *Lepidodendron*, and Calamites. The Conifers, also, are abundant, and belong to several genera. Some of the Conifers, however (as *Ullmania*), bear genuine cones, and the Sigillarioids, which are so characteristic of the Carboniferous period, have apparently altogether disappeared in the Permian.

With the Trias we commence the great series of Mesozoic

deposits, and there is a marked change in the vegetation of this period as compared with that of the Carboniferous and Permian epochs. The *Lepidodendroids* and *Sigillarioids* have now completely disappeared. The Calamites of the Coal-measures are represented by true Horse-tails (*Equisetites*). Ferns and Conifers are still abundant, and some of the latter (*Voltzia*) are by no means unlike existing forms. Lastly, there is an abundance of remains of Cycadaceous plants (*Pterophyllum, Podozamites,* &c.)

The Jurassic and Lower Cretaceous deposits are similarly characterised by an abundance of Cycads, Ferns, and Conifers, the first of these in particular constituting a marked feature in the vegetation.

In the Upper Cretaceous period[1] we have the first appearance, either absolutely, or certainly in any quantity, of ordinary Angiospermous Exogens, similar to those which predominate at the present day in the flora of temperate regions. Besides Ferns and Cycads more or less allied to Jurassic forms, we have now numerous Dicotyledonous trees, such as the Oak, Beech, Fig, Poplar, Walnut, Willow, Alder, &c., belonging to familiar genera now in existence. Here, also, we have the first appearance, so far as is certainly known, of the group of the Palms.

Of the vegetation of the Tertiary period, it is sufficient to remark here that now there is a marked predominance of Angiospermous Exogens and of Endogens as compared with Cryptogams and Gymnospermous Exogens. Not only is this the case, but many of the Tertiary plants approximate closely to existing forms, this approximation becoming more and more marked as we recede from the Eocene and approach the Recent period.

Before closing this brief review of the succession of plants upon the globe, it may be well to notice shortly a generalisation which was long since made by M. Adolphe Brongniart.

[1] It is impossible here to enter into the question as to whether the so-called "Lignitic Series" of North America, which rests upon undoubted Cretaceous strata, and is overlaid by unquestionable Lower Tertiary beds, and which has yielded such a number of Angiosperms of Tertiary type, is itself really referable to the Cretaceous or to the Eocene formation. It will here, on the strength of its animal remains, be regarded as of Cretaceous age.

This distinguished observer, in dividing the series of stratified deposits in accordance with the fossil plants contained in them, named the Palæozoic period the "Age of Acrogens," the Secondary period (exclusive of the Cretaceous) the "Age of Gymnosperms," and the Cretaceous and Tertiary periods the "Age of Angiosperms." This generalisation, though still expressing a general truth, can only be accepted with considerable reservation. Gymnosperms, and perhaps even Angiosperms, are not unknown in the Palæozoic period; and if the Sigillarioids should be referred to the former group of plants, then the later Palæozoic period would have as good claim to be called the "Age of Gymnosperms" as the Secondary period. Again, as pointed out by Sir Charles Lyell, the Lower and Upper Cretaceous floras differ from one another in the most striking manner, the Lower Cretaceous agreeing in this respect with the Jurassic series, whilst the Upper Cretaceous series is linked on by its plants to the Tertiary formations. The line, therefore, between the Age of Gymnosperms and the Age of Angiosperms must be drawn between the Lower and Upper Cretaceous, and not at the base of the Cretaceous series.

CHAPTER L.

PRE-CARBONIFEROUS FLORAS.

Cambrian Plants.—The Laurentian and Huronian deposits have as yet yielded no remains of plants; but the occurrence of graphite in large quantity in the former of these would strongly support the view that the Laurentian period was not without an abundant marine vegetation. The Lower Cambrian rocks have yielded many so-called "fucoids;" but these are almost invariably to be referred to the tracks and burrows of marine worms. The only generally admitted plant of the Lower Cambrian period is the *Eophyton* (fig. 696) of the "Fucoidal Sandstone" of Sweden.

The singular fossils referred to this genus consist of straight, furrowed, and striated stems, which can hardly be anything else than the remains of plants. The affinities, however, of these ancient fossils are quite undetermined, except that it seems pretty certain that they cannot be referred to the *Algæ;* and Principal Dawson is disposed to regard them as perhaps of inorganic origin.

In the Upper Cambrian rocks (Potsdam Sandstone) of North America occur various so-called "Fucoids" (*Palæophycus*, &c.) The true nature of these, however, is in many cases very doubtful, and it is questionable if any of them can really be regarded as plants.

Silurian Plants.—The remains of plants in the Silurian series are comparatively few in number, and require little consideration. In the Lower Silurian rocks a large number of fossils have been regarded as Sea-weeds, and referred to

the group of the "Fucoids," under the generic titles of *Palæophycus, Licrophycus, Buthotrephis, Phytopsis, Sphenothallus,* &c. Some of these appear to be nothing more than the tracks of Annelides. Others appear to be unquestionable

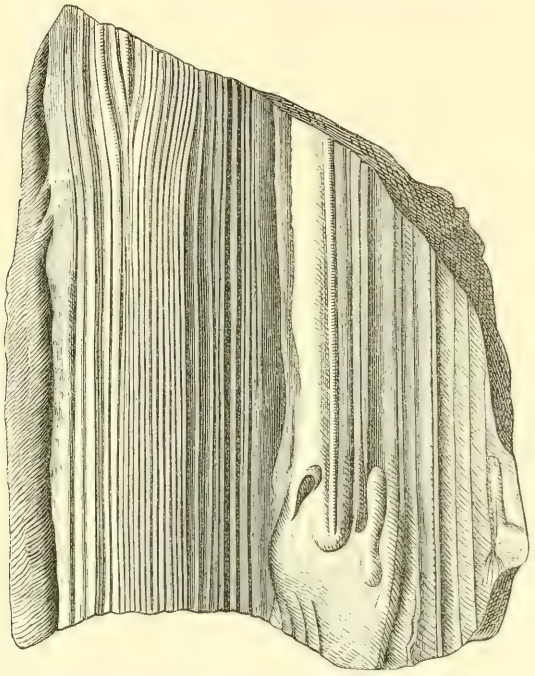

Fig. 696.—Fragment of *Eophyton Linneanum.* Lower Cambrian.

plants; but nothing positive can be stated as to their affinities. They may be *Algæ,* or they may belong to plants higher in the vegetable scale. Subjoined is an illustration of a characteristic Canadian species described by Mr Billings (fig. 697).

Here, also, we may briefly consider certain remains discovered by the author in the Skiddaw Slates of the North of England, a formation which is now generally regarded as belonging to the lowest division of the Lower Silurian series of Britain. The remains in question were originally referred provisionally to the genera *Buthotrephis* and *Eophyton,* and the fossils which led to the former determination appear to

be indubitable plants. They are thus described by Dr Dawson in a note communicated to the author:—

1. *Buthotrephis Harknessii.*—This consists of what have been cylindrical branches, given off from a central stem, and producing a few branchlets in the manner of *Pinnularia.* Under the microscope the branches show a vesicular structure; but this I believe to have been produced by the weathering out of minute globular concretions, probably of calcareous matter. The appearances are rather those of roots or slender herbaceous stems than of Algæ. If found in the Coal-measures it would probably be regarded as an obscure *Pinnularia.*

Fig. 697.—*Licrophycus Ottawaensis*, a "Fucoid" from the Trenton Limeston (Lower Silurian) of Canada. (After Billings.)

2. *Buthotrephis radiatus.*—This shows radiating branchlets or leaves (fig. 698), with the same vesicular structure as the preceding, and having some resemblance to the whorls of *Annularia,* though without any midrib.

It is quite possible that both of the above may belong to the same species. If a land-plant, allied to *Annularia,* the first may represent the roots or sub-aquatic stems, and the second its whorls of leaves. If an Alga, the first may represent branching fronds, and the latter the fructi-

fication. Under the former supposition, they may be compared with *Annularia laxa* of the Devonian, and the radiating root-like bodies associated with it.—(Dawson, Report on Devonian Flora.) Under the supposition that the plants are Algæ, they may be compared with *Sphærococcites Schurtzanus* of Goeppert, from the Silurian (Etage D.) of Bohemia, though they do not come under the technical definition of Sternberg's genus *Sphærococcites*.

Whether or not either of the above be truly referable to land-plants, Professor Leo Lesquereux has recently described from deposits of Lower Silurian age (Cincinnati Group), in North America, remains of a plant which he considers to be referable to a Sigillarioid, and therefore to be undoubtedly terrestrial. These remains he has referred to a special genus under the name of *Protostigma;* and if his determination be correct, we have here not only the most ancient undoubted land-plants known, but also the proof that even at this early period the terrestrial vegetation was of anything but a low order; since the *Sigillarioids*—wherever they may be ultimately placed—are unquestionably highly specialised types.

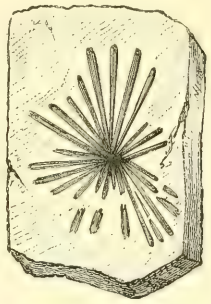

Fig. 698.—A small slab with one of the whorls of *Buthotrephis* (?) *radiatus* upon it, of the natural size. Lower Silurian (Skiddaw Slates) of the North of England. (Original.

In the Upper Silurian rocks are also numerous remains of "Fucoids" (*Arthrophycus, Dictuolites, Chondrites, Spirophyton,* &c.), which do not differ in any important point from those of the inferior division. Some of these can hardly be anything but true plants, and would certainly seem to be the remains of genuine Sea-weeds. Besides these, in many cases, problematical fossils, however, the Upper Silurian rocks have been shown to contain the remains of genuine land-plants. Thus, remains of the Lycopodiaceous genus *Lepidodendron* (*Sagenaria*) have been discovered in the Upper Silurian of Germany and Bohemia. At the summit of the Upper Silurian series in Britain have been detected numerous seed-vessels or "sporangia" referred by Hooker to a Lycopodiaceous plant under the generic title of *Pachytheca*. Lastly,

the Upper Silurian of North America has yielded remains of the characteristic Devonian genus *Psilophyton*, which will be described immediately, together with true Ferns (related to *Neuropteris*), and two forms allied to the great Devonian and Carboniferous family of the Calamites (namely, *Annularia* and *Sphenophyllum*).

Devonian Plants.—The plants of the Devonian period belong to the groups of the *Equisetaceæ* (Horse-tails), *Lycopodiaceæ* (Club-mosses), *Filices* (Ferns), Sigillarioids, and *Coniferæ*—the whole constituting an abundant terrestrial vegetation. Besides the above, however—as already mentioned—the remains of a true Angiospermous Exogen are stated to have been in one instance detected in Devonian strata (Dawson).

The *Equisetaceæ* are represented by species of the remarkable genus *Calamites*, the characters of which will be briefly spoken of when treating of the Coal-plants.

The *Lycopodiaceæ* are represented by the genera *Lepidodendron*, *Lycopodites*, *Leptophlœum*, *Lepidophloios*, and *Psilophyton*. The Lepidodendroids will be shortly discussed under the head of the plants of the Carboniferous series; but the genus *Psilophyton* merits special notice here.

The genus *Psilophyton* of Dawson (fig. 699) commences its existence in the Upper Silurian rocks; but it is characteristically Devonian, and is not known to be represented in the Carboniferous period. The following is given by Dr Dawson as the definition of the genus:—

"Stems branching dichotomously, and covered with interrupted ridges. Leaves rudimentary, or short, rigid, and pointed; in barren stems, numerous and spirally arranged; in fertile stems and branchlets, sparsely scattered or absent; in decorticated specimens represented by minute punctate scars. Young branches circinate; rhizomata cylindrical, covered with hairs or ramenta, and having circular areoles irregularly disposed, giving origin to slender cylindrical rootlets. Internal structure—an axis of scalariform vessels, surrounded by a cylinder of parenchymatous cells, and by an outer cylinder of elongated woody cells. Fructification consisting of naked oval spore-cases, borne usually

Fig. 699. — *Psilophyton princeps* (Dawson). *a*, Rhizome; *b*, Stem; *c*, Termination of a branch; *d*, Vernation; *e*, Fructification — all of the natural size; *g*, Areole of rhizome enlarged; *h*, Restoration of the plant, reduced. Devonian of Canada.

in pairs on slender curved pedicles, either lateral or terminal."

Species of *Psilophyton* occur all through the Devonian series of North America, and they are also not wanting in the Old Red Sandstone of Britain. The genus is regarded by Dr Dawson as comprising "synthetic or generalised plants, having rhizomata resembling those of some ferns, stems having the structure of *Lycopodium*, and rudimentary leaves also resembling those of *Lycopodiacea*, branchlets with circinate vernation like that of Ferns, and sporangia of a type quite peculiar to themselves." The genus, as has been seen, begins in the Upper Silurian.

The Ferns of the Devonian period are very numerous, and upon the whole present a close resemblance to those of the Carboniferous period. The smaller forms are represented by such genera as *Cyclopteris*, *Neuropteris*, *Sphenopteris*, *Alethopteris*, *Pecopteris*, &c. Besides these, however, there occur the trunks of large Tree-ferns, which are referred to the genera *Psaronius* or *Stemmatopteris*, *Caulopteris*, and *Protopteris*. Subjoined is an illustration of a Fern from the Devonian of Europe (fig. 700).

The *Sigillarioids* of the Devonian series comprise forms referable to the well-known genera *Sigillaria* (with *Stigmaria*) and *Calamodendron*; though the affinities of the last are not well understood. The characters of these genera will be noticed in treating of the plants of the Carboniferous series.

The remains of *Coniferæ* are by no means unknown in the Devonian rocks, and various generic types of this group are represented. The two principal genera of this period are *Dadoxylon* and *Ormoxylon*, both of which are exogenous trees with concentric rings of growth, their woody tissue exhibiting "discs" under the microscope. We may also place here the genus *Prototaxites* (fig. 701), which is found in the Lower Devonian of Canada, and which is regarded by Principal Dawson as being Coniferous. The trunks of *Prototaxites* vary in diameter from one to three feet, and exhibit concentric rings of growth; but its woody fibres have not yet been incontestably proved to possess discs. Mr Carruthers does not consider the Coniferous nature of *Pro-*

totaxites as sufficiently proved, and he thinks that the genus has been founded upon the trunks of gigantic Sea-weeds. Lastly, the genus *Cordaites* is now generally regarded as an ancient type of the Gymnosperms, though it is not clear that it is truly Coniferous. The genus is common both to the Devonian and the Carboniferous formations, and includes

Fig. 700.—*Sphenopteris laxus.* Devonian.

broad, striated, parallel-veined leaves, which are extremely abundant in certain beds. They possess broad clasping bases, and may attain a length of a foot and a breadth of as much as three inches.

According to Grand'Eury, *Cordaites* is a true Conifer, the sexes in which are in different individuals (as in the living Yew-tree). The organs of reproduction are slender spikes, the male ones bearing small scaly buds (supposed to be antheriferous) in the axil of bracts, while the female spikes carry single seeds in each axil. The same authority con-

siders that the genus *Antholithes* is in part founded upon the spikes of *Cordaites*, as also the genus *Cardiocarpon* upon its fruit; while the pith-cylinders form part of the genus *Sternbergia*, and the genus *Dadoxylon* simply comprises its woody trunk.[1]

In addition to the preceding forms, the Devonian rocks have yielded examples of the fossils known as *Sternbergia*,

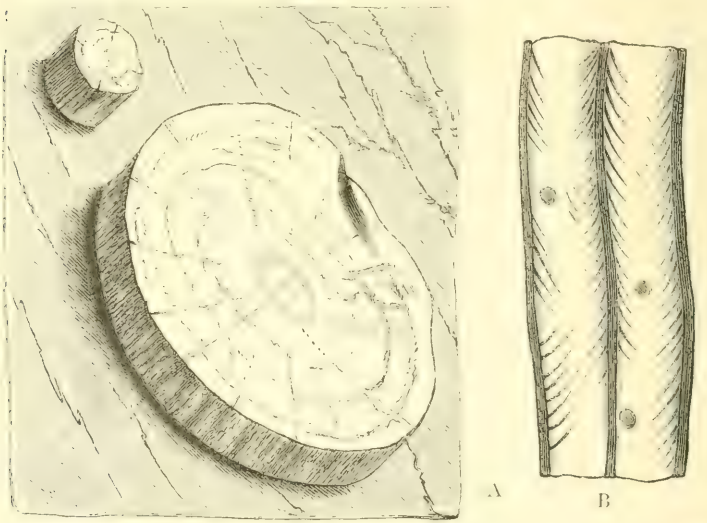

Fig. 701.—A, Trunk of *Prototaxites Logani*, eighteen inches in diameter, as seen in the cliff near L'Anse Brehaut, Gaspé; B, Two wood-cells showing spiral fibres and obscure pores, highly magnified. Lower Devonian, Canada. (After Dawson.)

Cyperites, *Asterophyllites*, *Annularia*, *Pinnularia*, *Cardiocarpon*, and *Trigonocarpon*. Of these, the genus *Sternbergia* comprises cylindrical, transversely-marked fossils, which are now known to be nothing more than the casts of the pith-cylinders of other plants. They seem chiefly to belong to Conifers of the genus *Dadoxylon*, but they are referable also to *Sigillaria*, and even to *Lepidodendron*. When the plant to which they belong is itself preserved, there is no difficulty

[1] This is a good instance of the difficulties which attend the study of Palæobotany, of the extent to which the best authorities are at variance with one another as to the true nature of even widely-distributed genera, and of the depth of the obscurity which still envelops many most important points connected with the structure of fossil plants.

in recognising the true nature of the *Sternbergiæ;* but when the outer wood has been denuded, it becomes almost impossible to determine to what plant they may have belonged. The genus *Cyperites* comprises elongated linear leaves, which appear truly to be the leaves of *Sigillariæ.* The genus *Asterophyllites* (fig. 702) comprises elegant plants with ribbed and jointed stems. The joints of the stems give off verticils of leaves, or branchlets bearing whorls of leaves, which are narrow, elongated, and furnished with a single midrib. According to some authorities, *Asterophyllites* is really founded upon the foliage of *Calamites.* The genus is not only found in the Devonian series, but is commonly represented in the Coal-measures, to which the species here figured belongs.

The genus *Annularia* comprises plants which are of doubtful affinities, but which possessed slender stems bearing at intervals whorls of leaves. The *Annulariæ* appear to have been floating plants, and they occur in both the Devonian and Carboniferous formations.

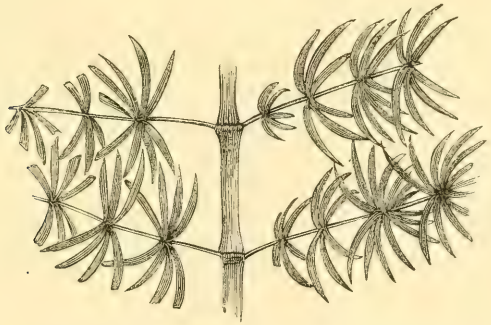

Fig. 702.—*Asterophyllites foliosus.* Coal-measures. (After Lindley and Hutton.)

The fossils known as *Pinnulariæ* are slender stem-like bodies, with a smooth or striate surface, producing at right angles long slender branchlets. The genus *Pinnularia* is regarded by Dawson as being founded upon the roots of other plants, such as *Asterophyllites* or *Calamites.*

Lastly, we find in the Devonian rocks the little fruits known as *Cardiocarpon* and *Trigonocarpon,* which are so

abundant in the Coal-measures. The *Cardiocarpa* appear mostly to have been winged achenes or "samaras;" but it is not altogether certain by what plants they were produced. It is now known, however, that the so-called *Antholithes* consists of a spike, bearing *Cardiocarpa* protected by bracts; and there is a considerable probability that they were produced by Sigillarioid trees. Good authorities, however, regard *Cardiocarpon* as really belonging to *Cordaites*. *Trigonocarpon* (fig. 703) comprises nut-like fruits, often of considerable size, and commonly three- or six-angled. The exterior of the fruit was probably fleshy, and well-preserved specimens show the integuments, and the internal cavity at one time filled by the albumen and embryo. *Trigonocarpon* is probably the fruit of a Conifer, and it shows a decided resemblance to the solitary fruit of the existing Taxoid genus *Salisburia*. Possibly, however, Dr Dawson is correct in his conjecture that most of the *Trigonocarpa* belonged really to Sigillarioid plants.

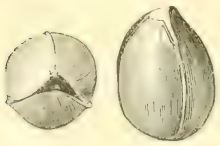

Fig. 703.—*Trigonocarpon ovatum*. Coal-measures. (After Lindley and Hutton.)

CHAPTER LI.

THE CARBONIFEROUS AND PERMIAN FLORAS.

Carboniferous Plants.—The most extensive and the best known of the Palæozoic Floras is that which flourished during the Carboniferous period. At this time were formed those vast accumulations of vegetable matter which we know as *coal;* and much of our information as to the Carboniferous plants is due to the value of coal, and to the vigour with which coal-mining has been prosecuted.

Coal consists of nearly pure carbon, with varying proportions of hydrogen and oxygen and a small quantity of mineral matter. The following are the conclusions arrived at by Dr Dawson as to the minute structure of coal: 1. The so-called "mineral charcoal" or "mother coal" consists chiefly of "bast-tissue" or of elongated cells derived from the inner bark of *Sigillariæ* and *Lepidodendra*. 2. Besides the above, the mineral charcoal contains in many instances scalariform tissue derived from Ferns, *Sigillariæ*, *Lepidodendra*, &c. 3. The coarse and laminated portions of the coal are made up of vascular bundles, derived apparently in the main from Ferns, along with other vegetable fragments, and in some cases, though not to a great extent, the sporangia of some of the Carboniferous Cryptogams. 4. In many parts of the coal occur discigerous or punctated woody fibres, belonging to *Dadoxylon*, *Sigillaria*, and *Calamodendron*. 5. A considerable portion of the coal is made up of "epidermal tissue," which is "a dense cellular tissue representing the outer integuments of various leaves, herbaceous stems, and fruits." 6. The layers of bright shining coal are composed of the flattened stems, and chiefly of the bark, of *Sigillariæ* and other trees. 7. Some layers of coal are occasionally composed mainly of the compressed leaves of *Cordaites*. 8. Sporangia are often present in coal; but they rarely exist in such a proportion as to any extent actually to form the coal themselves. In some of the English coals, however, the mass of the

coal is actually made up of the sporangia of Lycopodiaceous plants. The same thing is also occasionally seen in some shales, as, for example, in the black shale of Kettle Point, on Lake Huron, the age of which is Devonian. This shale is seen on inspection by the unassisted vision to be dotted all over with minute brown specks, which on a microscopic examination of thin slices (fig. 704) are found to be the spherical sporangia of some of the *Lycopodiaceæ* of the Devonian. The number of these sporangia present in the shale is enough to render it combustible, with some difficulty : but it is not, of course, in any sense a true coal.

As has been already observed, the types of plants which are found in the Carboniferous rocks are to a great extent identical with those which composed the Devonian flora. *Specifically*, however, the coal-plants are almost always distinct from the Devonian forms. The number of plants already known to have existed during the Carboniferous period is so great, that nothing more can be done here than to draw the attention of the student to some of the more important and characteristic types.

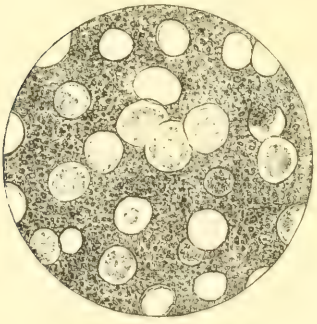

Fig. 704.—A thin slice of shale from Kettle Point, Lake Huron, showing sporangia of Club-mosses, greatly magnified. Devonian. (Original.)

a. Filices.—The Ferns of the Carboniferous period are extremely numerous, and include both herbaceous forms like the majority of existing species, and arborescent forms similar to the living Tree-ferns of New Zealand. The latter belong to the genera *Psaronius*,[1] *Caulopteris*, and *Palæopteris*, of which the two former occur in the older Devonian period. Of the smaller ferns, the genera *Sphenopteris*, *Pecopteris*, *Alethopteris*, *Odontopteris*, *Neuropteris*, *Hymenophyllites*, and *Cyclopteris* may be mentioned as the most important and widely distributed. In the genus *Neuropteris* (fig. 705) the midrib of the leaflets is evanescent, either not distinct, or disappearing towards the apex. Species of this genus are

[1] *Psaronius* appears to be the internal structure of the stems of Tree-ferns, of which the genus *Stemmatopteris* is the external aspect.

found in the coal-formation over almost the whole world. In *Alethopteris* the leaflets are attached by their bases to the stem and to one another, and are provided with a very distinct midrib from which the veins are given off nearly at right angles. The commonest species is the cosmopolitan *Alethopteris* (*Pecopteris*) *lonchitica*, which nearly resembles

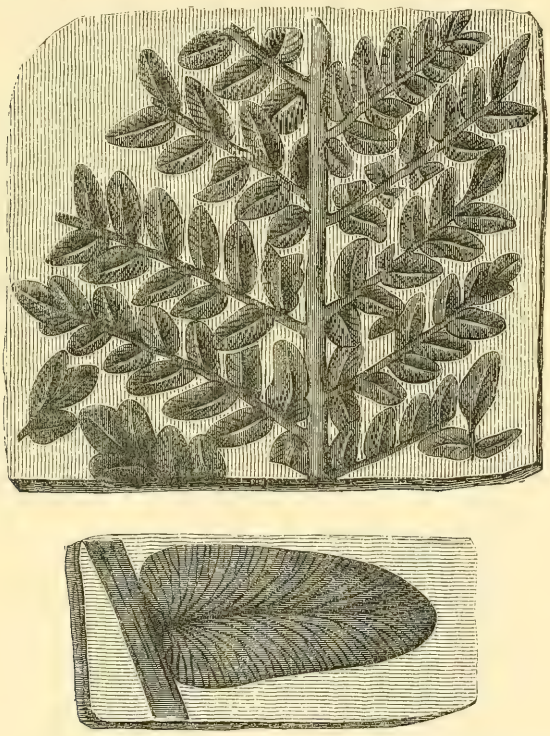

Fig. 705.—*Neuropteris heterophylla*. Coal-measures of Europe. The lower figure shows a single leaflet enlarged.

the living Brackens (*Pteris aquilina*). Nearly allied to *Alethopteris* is the genus *Pecopteris*, which includes a large number of characteristic Carboniferous species. In *Odontopteris* (fig. 706) the frond is pinnate, the leaflets being attached by their entire bases, and the veins are generally given off from the base. The species here figured is a widely-distributed one, occurring in both Europe and North

America. In the genus *Sphenopteris*, the leaflets are narrow towards their bases, often assuming a wedge-like form, the nervures dividing in a pinnate manner from the base.

Fig. 706.—*Odontopteris Schlotheimii*. Carboniferous of Europe and North America.

Lastly, in the genus *Hymenophyllites* the frond exhibits a general resemblance to *Sphenopteris*, but the margin is divided into lobes, into each of which a single nervure is continued.

b. Calamites.—Amongst the commonest and most characteristic of the plants of the Carboniferous period are the striated fossils which are known as *Calamites*. Long as these have been known, and carefully as they have been studied, there is still no unanimity of opinion as to the affinities of these plants. It is now, however, generally admitted that the *Calamites* are truly referable to the *Equisetacea*, and that they may be regarded as gigantic Horse-tails—though they differ in many respects from any existing forms. The *Calamites* were "slender, ribbed, and jointed externally, and from the joints there proceeded, in some of the species, long, narrow, simple branchlets; and, in others, branches bearing whorls of small branchlets or rudimentary leaves. The stem was hollow, with thin transverse floors or diaphragms at the joints, and it had no true wood and bark, but only a thin external shell of fibres and scalariform vessels.

The *Calamites* grew in dense brakes on the sandy and muddy flats, subject to inundation, or perhaps even in the water, and they had the power of budding out from the base of the stem, so as to form clumps of plants, and also of securing

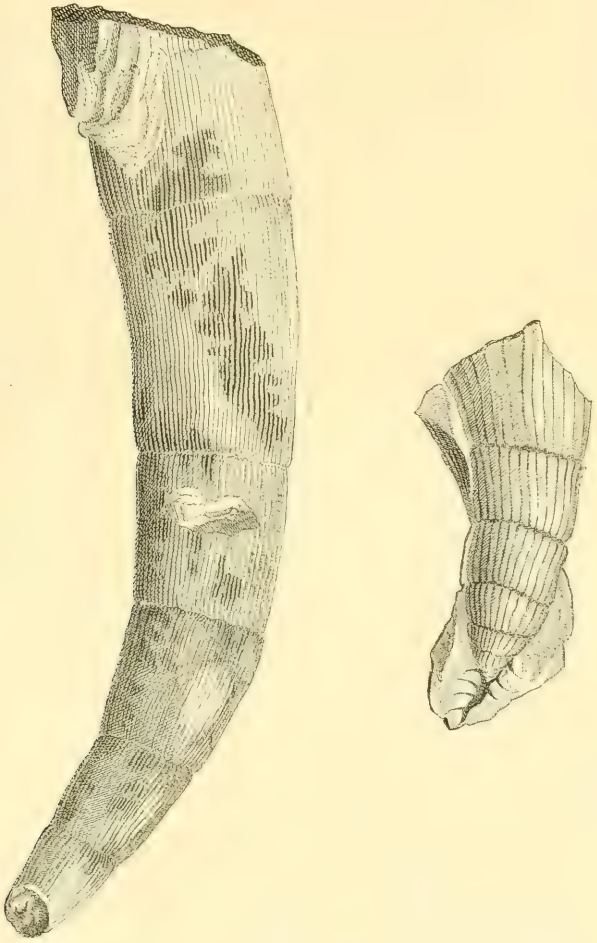

Fig. 707.—*Calamites cannæformis.* Carboniferous of Europe and North America.

their foot-hold by numerous cord-like roots proceeding from various heights on the lower part of the stem. The fruit was a long cone or spike, bearing spore-cases under scales "

(Dawson, Acadian Geology, p. 441). Besides the true *Calamites*, the Carboniferous rocks have also yielded the remains of the genus *Equisetites*, which differed from the *Calamites*, and agrees with the existing Horse-tails in having sheaths at the joints.

Calamites often attain a comparatively gigantic size—twenty feet or more in length; and though they generally occur as prostrate and flattened stems, they are not uncommonly found in an erect and uncompressed condition, standing as they grew. The fossils known as *Asterophyllites* have been referred to *Calamites*, of which they are sometimes supposed to constitute the foliage; but this opinion is not accepted by high authorities.

c. Calamodendron.—A good deal of the confusion which has prevailed as to the true nature of *Calamites* appears to have arisen out of the uncertainty which has long prevailed as to the true nature of the problematic fossils now generally referred to the genus *Calamodendron*. As ordinarily found, *Calamodendra* present themselves in the form of jointed and longitudinally-ribbed cylindrical stems, which are hardly separable from *Calamites*, except that they show no "areoles," or points whence leaves or branchlets have been given off. From the examination, however, of complete specimens, it has been shown that *Calamodendron*, as thus constituted, is really nothing more than the cast of the pith or medullary cavity of a complex woody stem, thus resembling in its nature the fossils known as *Sternbergia*. Round the internal axis thus constituted there is found in perfect examples a thick woody envelope, composed of ligneous wedges arranged concentrically and separated by intervening tracts of cellular tissue (or "medullary rays"). The external surface of the stem is not known, but the woody wedges are stated to consist of "elongated cells, and porous, discigerous, or pseudo-scalariform tissue." The affinities of *Calamodendron* are uncertain. It is regarded by different authorities as belonging to the Gymnospermous Exogens or to the Acrogens, or as a connecting form between these groups. Upon the above view, it is necessary to distinguish very carefully between *Calamodendron* and *Calamites*, the

latter being clearly separated by the absence of a woody envelope, and the presence of whorled leaves or branchlets at the articulations of the stem.

On the other hand, it must be said that extremely strong evidence has been brought forward to show that there is no real distinction between *Calamites* and *Calamodendron*, but that the two are simply different states of preservation of the same plant. This view is supported strongly by Professor Williamson, one of the ablest of living palæobotanists, who holds that the supposed absence of a woody envelope in *Calamites* is simply due to the fact that in certain specimens, and in certain deposits, this structure has been destroyed prior to ordinary fossilisation, whereas in others it has been preserved. Considering how often the internal structure of the Carboniferous plants has been destroyed during mineralisation, and how comparatively seldom it has been retained, there is much to be said for the correctness of this view.

d. Lepidodendroids.—Under this head we have to consider the genera *Lepidodendron* and *Lepidophloios*, generally regarded as gigantic extinct members of the Club-moss family (*Lycopodiaceæ*). The genus *Lepidodendron* (fig. 708) comprises numerous large arborescent plants, which attain their maximum in the Carboniferous period, but which appear to commence in the Upper Silurian, and are well represented in the Devonian. The trunk in some cases reached a length of fifty feet or more, and the branches are given off in a regular, bifurcating manner. The bark is marked with numerous rhombic or oval scars, arranged in quincunx order, and indicating the points where leaves were formerly attached. The branches were covered with slender, pointed leaves, closely crowded together; and the fructification was carried at the ends of the branches in the form of cones or spikes. These cones have generally been described under the name of *Lepidostrobi;* and they consist of a central axis, surrounded by imbricated scales or bracts, each of which supports a sporangium or spore-case.

In internal structure, *Lepidodendron* possesses a large central pith, surrounded by a continuous sheath of scalariform

vessels. Outside this, again, is a thick bark, composed mainly of elongated fibres or "bast-tissue," with a thin dense outer rind.

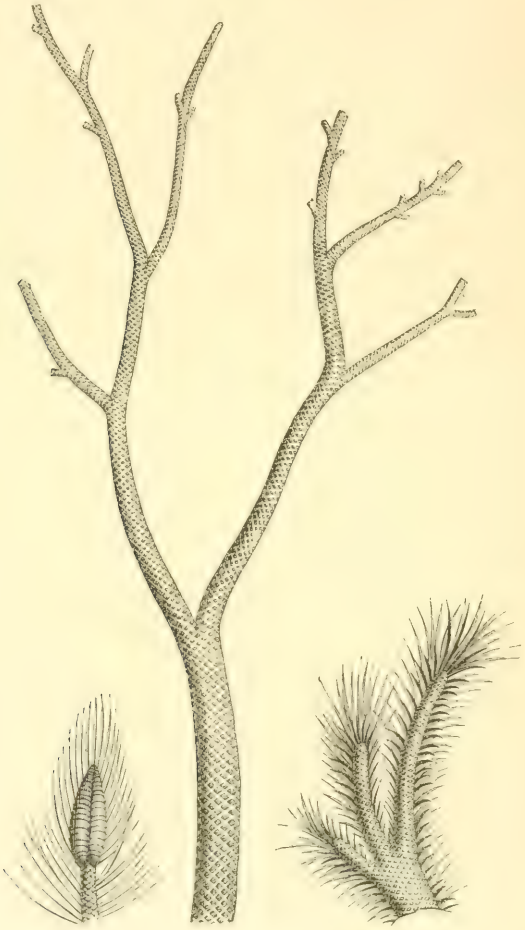

Fig. 708.—*Lepidodendron Sternbergii.* Carboniferous.

The genera, or sub-genera, *Sagenaria*, *Knorria*, and *Aspidiaria*, are properly to be referred to *Lepidodendron*. The genus *Lepidophloios*, however, is represented both in Devonian and Carboniferous rocks by forms which are generically distinct from *Lepidodendron*. The genus includes

Lycopodiaceous trees which have "thick branches, transversely-elongated leaf-scars, each with three vascular points, and placed on elevated or scale-like protuberances, long one-nerved leaves, and large lateral strobiles in vertical rows or spirally disposed" (Dawson).

e. Sigillarioids.—The three chief genera included under this head are *Sigillaria*, *Rhytidolepis*, and *Favularia*, of which the first is the most important. The Sigillarioids commence their existence, so far as known, in the Devonian period, but they attain their maximum in the Carboniferous; and—unlike the Lepidodendroids—they are not known to occur in the Permian period. They are comparatively gigantic in size, often attaining a height of from thirty to fifty feet or more; but though abundant and well preserved, great divergence of opinion prevails as to their true affinities. The *name* of Sigillarioids (Lat. *sigilla*, little seals or images) is derived from the fact that the bark is marked with seal-like impressions or leaf-scars (fig. 709).

According to Dawson, *Sigillaria* proper is distinguished by its strong ribs, "which are usually much broader than the

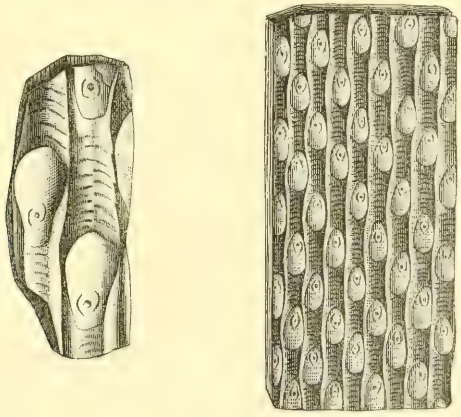

Fig. 709.—Fragment of *Sigillaria Græseri*. The left-hand figure shows a small portion enlarged. Carboniferous.

oval or elliptical tripunctate areoles, and are striated longitudinally." The stem consists of a central pith, which is transversely partitioned, as in the so-called *Sternbergiæ*. The

pith is surrounded by a woody cylinder, consisting of ligneous wedges, composed of punctated (discigerous) and scalariform vessels, and separated by medullary rays. Outside the woody axis is an inner bark composed of long durable fibres of "bast-tissue," the whole surrounded by a thick outer bark of dense cellular tissue. "The trunk when old lost its regular ribs and scars, owing to expansion, and became furrowed like that of an Exogenous tree." The roots, as will be seen immediately, constitute the fossils known as *Stigmaria*. The leaves are believed to be the so-called *Cyperites*, long, narrow, rigid, and two- or three- nerved. The fruits are supposed to be *Trigonocarpa*, "borne in racemes on the upper part of the stem." Upon the whole, Dr Dawson is disposed to adopt the view, originally put forth by Brongniart, that the *Sigillariæ* find their nearest living allies in the Cycads and that if not actually referable to the Gymnospermous Exogens, they may be intermediate between these and the higher Acrogens.

Mr Carruthers, on the other hand, describes *Sigillaria* as consisting of a central cellular pith or medulla, surrounded by a sheath consisting wholly of scalariform vessels, the whole enveloped in an external cortical mass of cellular tissue. The medullary sheath is perforated by meshes for the passage outwards of the vascular bundles which go to the axial appendages (the leaves and branches); but there are no true medullary rays. Upon these grounds, Mr Carruthers decides against the view that *Sigillaria* is a Gymnospermous Exogen, and he regards it as Cryptogamic and Lycopodiaceous. He also discredits the assertion that discigerous tissue is present, and describes the fruit as consisting of cones or strobiles.

Leaving the botanical position of *Sigillaria* thus undecided, we find that it is now almost universally conceded that the fossils originally described under the name of *Stigmaria* are the *roots* of *Sigillaria*, the actual connection between the two having been in numerous instances demonstrated in an unmistakable manner. The *Stigmariæ* (fig. 710) ordinarily present themselves in the form of long, compressed or rounded fragments, the external surface of which is covered with rounded pits or shallow tubercles, each of which has a little

pit or depression in its centre. From each of these pits there proceeds, in perfect examples, a long cylindrical rootlet; but in many cases these have altogether disappeared. In its internal structure, *Stigmaria* exhibits a central pith surrounded by a sheath of scalariform vessels, the whole enclosed in a

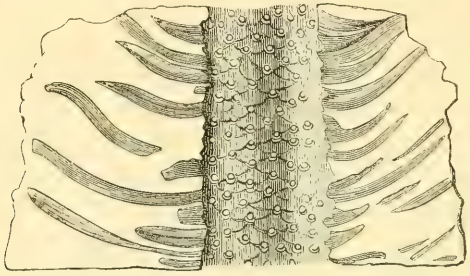

Fig. 710.—*Stigmaria ficoides*, one fourth of the natural size. Carboniferous.

cellular envelope. The *Stigmariæ* are generally found ramifying in the "underclay," which forms the floor of a bed of coal, and which represents the ancient soil upon which the *Sigillariæ* grew.

Of the remaining genera of the Sigillarioids, *Rhytidolepis* is the most important. It is characterised by the possession of large, hexagonal, tripunctate areoles, and narrow, often transversely striate ribs. In *Favularia*, lastly, the smaller branches were destitute of ribs, with elliptical, spirally-disposed areoles. The stem branched dichotomously—like that of a *Lepidodendron*—and the leaves were broad, with numerous parallel veins, approximating to the leaves of *Cordaites*.

f. Coniferæ.—True Conifers have long been known to occur in the Carboniferous rocks. They belong to the genera *Dadoxylon*, *Palæoxylon*, *Araucarioxylon*, and *Pinites*. They are recognised by the great size and concentric rings of their prostrate, rarely erect trunks, and by the fact that the microscope exhibits punctated fibres in their wood. Their fruit is unknown, unless, as is very probable, it is constituted by the so-called *Trigonocarpa*. If this be the case, the Carboniferous Conifers must have been "Taxoid," resembling the recent Yews in producing berries instead of true cones. The so-

called *Sternbergiæ*, as has been already pointed out, are "pith-cylinders," or, in other words, casts of the pith, of *Dadoxylon*. They appear, however, to belong also to *Sigillaria* and *Lepidophloios*.

g. Cycadaceæ.—The peculiar group of Gymnospermous Exogens represented at the present day by the Cycads is not known with certainty to be represented in the Carboniferous rocks. *Nœggerathia* has been referred here, and the Cycadaceous genus *Pterophyllum* has also been alleged to occur. Brongniart has also conjectured that the *Sigillarioids* are in reality most nearly allied to the *Cycadaceæ;* and this opinion is supported by other high authorities.

h. Angiospermous Exogens.—The occurrence of true Angiosperms in the Carboniferous period is very doubtful. No Exogenous wood which is not Coniferous has been as yet detected. The fossil known as *Antholithes*, which was at one time conjectured to be possibly the inflorescence of an Angiosperm, has now been shown to be really a raceme bearing the fruit termed *Cardiocarpon;* and it remains uncertain to what plant this really belongs.

i. Monocotyledons.—The occurrence of Endogens in the Coal-formation is also attended with some uncertainty. The genus *Nœggerathia* has sometimes been referred to the Palms, and the same group has been asserted to be represented by species of *Palmacites*. The curious twisted bodies referred to the genus *Spirangium* are supposed to be the fruits of *Monocotyledons*, but their true nature is uncertain. The only apparently unequivocal proof of the occurrence of Carboniferous Endogens is, however, afforded by the so-called *Pothocites*, which appears to have been the spadix of an Aroideous plant; but even this determination is not free from doubt.

Permian Plants.—The Permian Flora is, upon the whole, very nearly allied to that of the Coal-measures, though the Permian species are mostly distinct, and there are some new genera. Thus, we find species of *Lepidodendron*, *Calamites*, *Equisetites*, *Asterophyllites*, *Annularia*, &c.—all genera which are highly characteristic of the Carboniferous period. On the other hand, the Sigillarioids of the Coal appear to have finally passed away with the close of the Carboniferous period.

Ferns are abundant in the Permian rocks, and belong for the most part to the well-known Carboniferous genera *Alethopteris, Neuropteris, Sphenopteris,* and *Pecopteris.* There are also Tree-ferns referable to the genus *Psaronius.* The singular genus *Nœggerathia* (fig. 711) is represented in the Permian, and is supposed, with more or less probability, to be a Cycadaceous plant. It has pinnate leaves, with cuneiform leaflets, the venation of which resembles that of some Cycads.

The Conifers of the Permian period are numerous, and

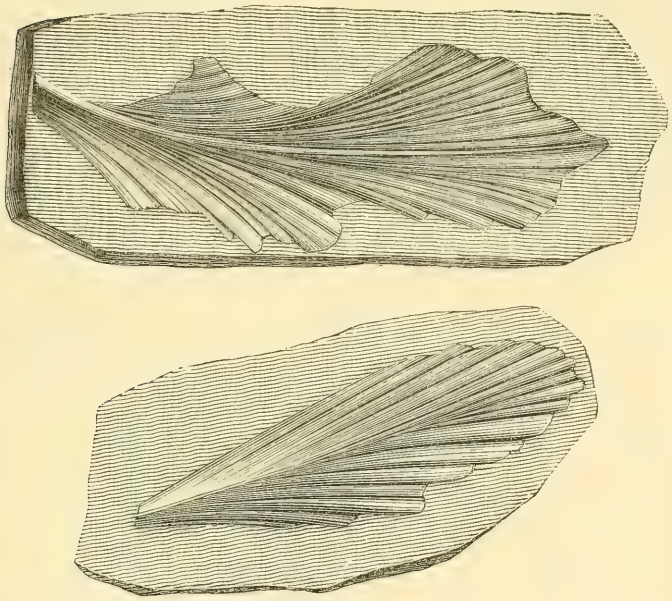

Fig. 711.—*Nœggerathia expansa.* Permian.

belong in part to Carboniferous genera. A characteristic genus, however, is *Walchia* (fig. 712), distinguished by its lax short leaves. This genus, though not exclusively Permian, is mainly so, the best-known species being the *W. piniformis.* Here, also, we meet with Conifers which produce true cones, and which differ, therefore, in an important respect from the Taxoid Conifers of the Coal-measures. One of the most characteristic of these is the *Ullmania selaginoides,* which

occurs in the Magnesian Limestone of Durham, the Middle Permian of Westmorland, and the "Kupfer-schiefer" of Germany.

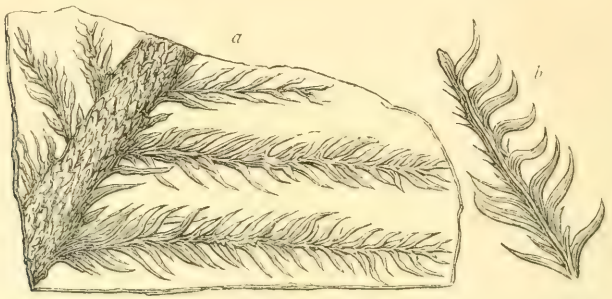

Fig 712.—*Walchia piniformis*. *a*, Branch; *b*, Twig. From the Permian of Saxony. (After Gutbier.)

CHAPTER LII.

FLORAS OF THE SECONDARY AND TERTIARY PERIODS.

Triassic Plants.—With the Trias we commence what has been aptly termed the "Age of Cycads," from the predominance of the plants of this group in the Mesozoic vegetation. The Cycads are a group of Gymnospermous Exogens, the form and habit of growth of which present considerable resemblance to those of young Palms (fig. 713). The trunk is

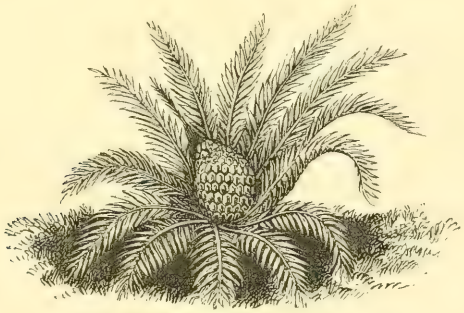

Fig. 713.—*Zamia spiralis*, a living Cycad. Australia.

unbranched, often shortened, and bearing a crown of pinnate fronds. The leaves are usually "circinate"—that is, they unroll in expanding, like the fronds of Ferns. The ovules are borne upon the edge of altered leaves, or are carried on the scales of a cone. All the existing species of Cycads are natives of warm countries, occurring in South America, the

West Indies, Japan, Australia, Southern Asia, and South Africa. As has been already remarked, the occurrence of genuine Cycads in the Carboniferous vegetation has not been demonstrated, and the same holds good of all the Palæozoic floras. True Cycads, therefore, so far as known, make their first appearance in the Trias, at the commencement of the Mesozoic period, where they are represented by the genera *Pterophyllum*, *Zamites*, and *Podozamites*. Cycads continue to be abundantly represented throughout the whole Mesozoic series; but they have only been detected by a single dubious example in strata of Tertiary age. The name "Age of Cycads," as applied to the Secondary epoch, is therefore, from a botanical point of view, an exceedingly appropriate one.

Besides Cycads, the Triassic rocks have yielded the remains of Ferns, *Equisetites*, Calamites, and Conifers. The Ferns belong mostly to the genera *Neuropteris*, *Pecopteris*, *Acrostichites*, *Crematopteris*, *Cyclopteris*, and *Anomopteris*. A characteristic species of the first of these is figured below (fig. 714). The Conifers of the Trias, lastly, are abundant, the most characteristic genus being *Voltzia*.

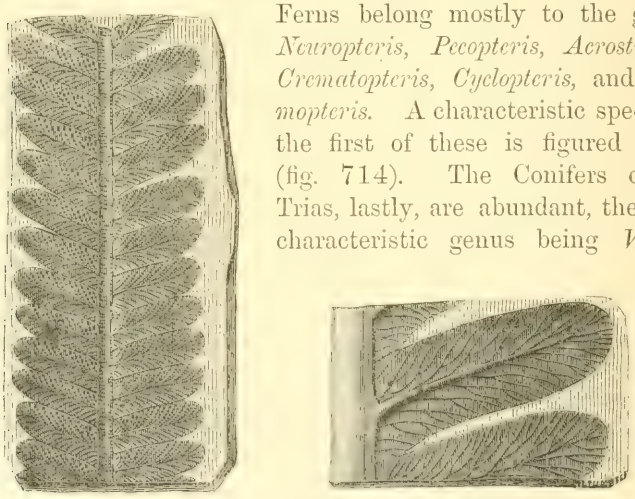

Fig. 714.—*Neuropteris elegans*. Trias.

This genus is related to the existing Cypresses, and many species of it are found in the Triassic rocks.

Jurassic Plants.—Taken as a whole, the Jurassic period is characterised by the prevalence of Ferns, Cycads, and Conifers; no Palms or Angiospermous Exogens having been as yet shown to occur.

The Cycads are extremely abundant, and belong chiefly to the genera *Pterophyllum, Otozamites, Zamites, Bucklandia, Crossozamia, Williamsonia, Mantellia,* &c. The "dirt-bed," as it is called, of the Purbeck beds, consists of an ancient soil, in which stand erect the trunks of Conifers and the stems of Cycads of the genus *Mantellia* (fig. 715). The fronds of Cycads occur also in great abundance in various Jurassic strata, especially in the lower portion of the series; and the cones likewise have been in some instances preserved. The Conifers are represented by various genera more or less nearly allied to the present *Araucariæ,* and cones have been in a few instances detected.

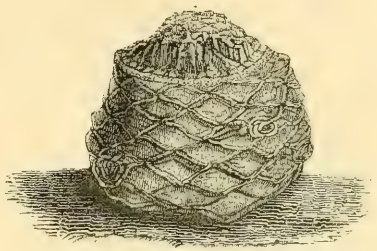

Fig. 715.—*Mantellia* (*Cycadeoidea*) *megalophylla,* a Cycad from the Purbeck "dirt-bed." Upper Oolites.

Ferns occur very abundantly in the Jurassic series, the commonest genera being *Coniopteris* (fig. 716), *Odontopteris* (fig. 717), *Sphenopteris, Cyclopteris, Phlebopteris, Pecopteris, Polypodites, Pachypteris,* and *Tæniopteris.*

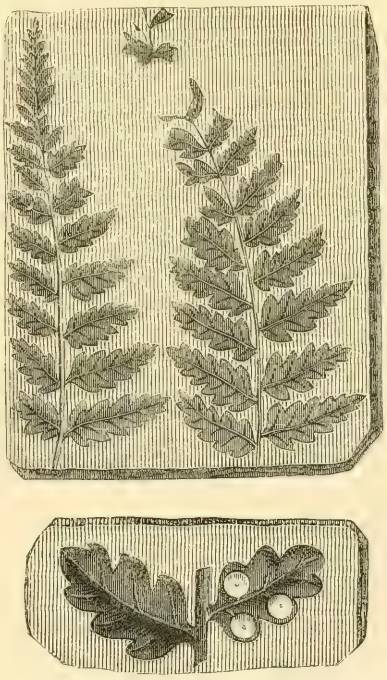

Fig. 716.—*Coniopteris Murrayana.* Great Oolite.

Endogens are by no means unknown in the Jurassic series, though no representative of the group of the Palms has been as yet detected. Amongst the most important of the Oolitic Endogens may be men-

tioned the Aroideous fruit described by Mr Carruthers under the name of *Aroides Stutterdi*, and the fruits known as *Podocarya* and *Kaidacarpum*, both of which belong to the living order of the *Pandaneæ* (Screw-pines).

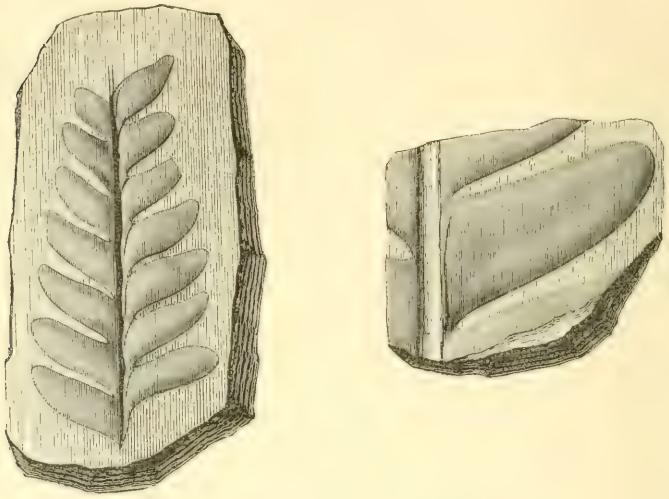

Fig. 717.—*Odontopteris cycadea*. Lower Lias.

Cretaceous Plants. — The Lower Cretaceous Plants greatly resemble those of the Jurassic period, consisting mainly of Ferns, Cycads, and Conifers. The Upper Cretaceous rocks, however, both in Europe and in North America, have yielded an abundant flora which resembles the existing vegetation of the globe in consisting mainly of Angiospermous Exogens and of Monocotyledons. In Europe, the plant-remains in question have been found chiefly in certain sands in the neighbourhood of Aix-la-Chapelle, and they consist of numerous Ferns, Conifers (such as *Cycadopteris*), Screw-pines (*Pandanus*), Oaks (*Quercus*), Walnut (*Juglans*), Fig (*Ficus*), and many *Proteaceæ*, some of which are referred to existing genera (*Dryandra, Banksia, Grevillea*, &c.)

In North America, the Cretaceous strata of New Jersey, Alabama, Nebraska, Kansas, &c., have yielded the remains

of numerous plants, many of which belong to existing genera. Amongst these may be mentioned Tulip-trees (*Liriodendron*), Sassafras (fig. 718), Oaks (*Quercus*), Beeches (*Fagus*), Plane-trees (*Platanus*), Alders (*Alnus*), Dog-wood (*Cornus*), Willows (*Salix*), Poplars (*Populus*), Cypresses (*Cupressus*), Bald Cypresses (*Taxodium*), Magnolias, &c. Besides these, however, there occur other forms which have now entirely disappeared from North America—as, for example, species of *Cinnamomum* and *Araucaria*.

Fig. 718.—Cretaceous Angiosperms. *a*, *Sassafras Cretaceum*; *b*, *Liriodendron Meekii*; *c*, *Leguminosites Marcouanus*; *d*, *Salix Meekii*. (After Dana.)

The most important plant-remains of the American Cretaceous rocks have, however, been obtained from a remarkable series of beds known as the "Lignitic Formation," which is largely developed in the Western or Rocky Mountain region, and the precise geological position of which has been a subject of great controversy, and is still unsettled. In the Old World, as is well known, there is a great break between

the highest Cretaceous and the lowest Tertiary sediments—a break marked not only by a universal unconformity, but also by a great change in the characteristic fauna of the two deposits. On the other hand, in North America the highest unquestioned Cretaceous beds (the marine deposits of the Fox-Hills group) are succeeded by a great series of strata, well known as the Fort Union or Great Lignite series, the true stratigraphical position of which has been the subject of much dispute. These deposits consist of nearly four thousand feet of sandstones, shales, and beds of lignite, which rest quite conformably upon the unquestioned Cretaceous deposits of the Fox-Hills group below, and which are succeeded unconformably by unquestioned beds of Tertiary age. In their lower portion they contain a number of marine organic remains, but these gradually disappear as we ascend in the series, and its upper portion is generally characterised by the remains of land and fresh-water shells, associated with a vast abundance of vegetable fossils, chiefly of the nature of detached Dicotyledonous leaves. The difficulty of the problem as to the real age of this great and remarkable deposit arises chiefly from the fact that its marine fossils are fundamentally of a Cretaceous type, whilst the remains of plants have an equally distinct Tertiary facies. Thus we find such characteristic Cretaceous Mollusca as *Inoceramus, Ammonites,* and *Baculites,* with unquestionable Dinosaurians (*Agathaumas*), side by side with a luxuriant flora of an essentially Tertiary aspect, comprising such modern genera as *Quercus, Acer, Populus, Ulmus, Morus, Fagus, Juglans, Alnus, Corylus, Ilex, Platanus, Ficus, Cinnamomum, Smilax, Laurus, Rhamnus, Magnolia, Eucalyptus, Thuja, Sequoia, Abies, Taxodium, Sabal,* &c. Whilst this association of Cretaceous animals with Tertiary plants is undoubted, much difference of opinion obtains as to how it ought to be interpreted. On the one hand, high authorities, such as Dr Heer, and Professors Lesquereux and Dana, are of opinion that the plants ought to carry the day, and that the Lignitic Group ought to be considered as the base of the Tertiary series. On the other hand, equally high authorities, such as

Meek, Hayden, Cope, and Stevenson, are of opinion that the fauna carries more weight than the flora, and that the Fort Union or Lignitic series should be regarded as truly the summit of the Cretaceous. To this view Prof. Newberry, who is in the rare position of having attained almost equal eminence in Palæozoology and Palæobotany, gives his adhesion; and it is to be considered as in every respect the most probable view, if we take into account the fact that the disputed series is admittedly overlain unconformably by strata of undoubted Tertiary age. Upon the whole, then, when we take into consideration the general unreliability of terrestrial or fresh-water Mollusca as tests of age, and also the often unsatisfactory nature of stratigraphical conclusions based upon vegetable remains only, we can hardly avoid arriving at the opinion that the Great Lignitic series of North America is truly Cretaceous, though probably of a later date than any of the recognised Cretaceous deposits of the Old World.

Admitting that the "Lignitic Formation" of Western North America is truly of Cretaceous age, it follows that the Lower and Upper Cretaceous rocks are, from a botanical point of view, sharply separated from one another. The Palæozoic period, as we have seen, is characterised by the prevalence of "Flowerless" plants (*Cryptogams*), its higher vegetation consisting almost exclusively of Conifers. The Mesozoic period, as a whole, is characterised by the prevalence of the Cryptogamic group of the Ferns, and the Gymnospermic groups of the Conifers and the Cycads. Up to the close of the Lower Cretaceous, no Angiospermous Exogens are certainly known to have existed, and Monocotyledonous plants or Endogens are very poorly represented. With the Upper Cretaceous, however, a new era of plant-life, of which our present is but the culmination, commenced, with a great and apparently sudden development of new forms. In place of the Ferns, Cycads, and Conifers of the earlier Mesozoic deposits, we have now an astonishingly large number of true Angiospermous Exogens, many of them belonging to existing types; and along with these are various Monocotyledonous

plants, including the first examples of the great and important group of the Palms. It is thus a matter of interest to reflect that plants closely related to those now inhabiting the earth, were in existence at a time when the ocean was tenanted by Ammonites and Belemnites, and when land and sea and air were peopled by the extraordinary extinct Reptiles of the Mesozoic period.

Eocene Plants.—The plants of the Eocene period approximate on the whole to the existing vegetation of the earth. They are, however, in the main most closely allied to forms which now are found in tropical or sub-tropical regions. In the London Clay occur numerous fruits of Palms (*Nipadites*, fig. 719), along with various other plants, most of which indicate a warm climate as prevailing in the South of England at the commencement of the Eocene period. In the Eocene strata of North America occur numerous plants, such as palms, conifers, magnolia, cinnamon, fig, dog-wood, maple, hickory, poplar, plane-trees, &c. Upon the whole, the Eocene flora of North America is nearly related to that of the Miocene strata of Europe, as well as to that now existing in the American area. We may conclude, therefore, that "the forests of the American Eocene resembled those of the European Miocene, and even of modern America" (Dana).

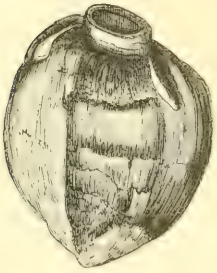

Fig. 719.—*Nipadites ellipticus*. London Clay of Sheppey.

Miocene Plants.—The deposits of the Miocene period have yielded an extraordinarily large number of plants, only a few of the more important of which can be indicated here. Our chief sources of information as to the vegetation of the Miocene period are derived from the Brown Coals of Germany and Austria, the Lower and Upper Molasse of Switzerland, and the Miocene strata of the Arctic regions. The lignites of Austria have yielded very numerous plant-remains, chiefly of a tropical character; one of the most noticeable forms being a Palm of the genus *Sabal* (fig. 720, B), now found in

America. The plants of the Lower Miocene of Switzerland are also mostly of a tropical character, but include several forms now found in North America, such as a Tulip-tree (*Liriodendron*) and a Cypress (*Taxodium*). Amongst the more remarkable forms from these beds may be mentioned Fan-Palms (*Chamærops*, fig. 720, A), numerous tropical ferns,

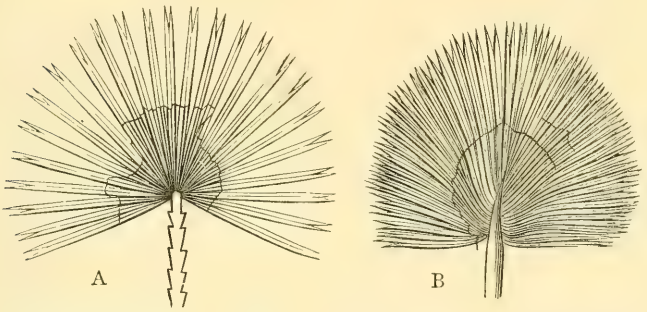

Fig. 720.—Miocene Palms. A, *Chamærops Helvetica*; B, *Sabal major*. Lower Miocene of Switzerland and France.

and two species of Cinnamon. The plant-remains of the Upper Molasse of Switzerland indicate an extraordinarily rank and luxuriant vegetation, composed mainly of plants which now live in warm countries. Among the commoner plants of this formation may be enumerated many species of Maple (*Acer*), Plane-trees (*Platanus*, fig. 721), Cinnamon-trees, and other members of the *Lauraceæ*, many species of *Proteaceæ* (*Banksia*, *Grevillea*, &c.), several species of Sarsaparilla (*Smilax*), Palms, Cypresses, &c.

In Britain, the Lower Miocene (Eocene ?) strata of Bovey Tracy have yielded remains of Ferns, Vines, Fig, Cinnamon, *Proteaceæ*, &c., along with numerous Conifers. The most abundant of these last is a gigantic pine—the *Sequoia Couttsiæ*—which is very nearly allied to the huge *Sequoia* (*Wellingtonia*) *gigantea* of California. A nearly-allied form (*Sequoia Langsdorffii*) has been detected in the leaf-bed of Ardtun in the Hebrides.

In Greenland, as well as in other parts of the Arctic regions, Miocene strata have been discovered which have

yielded a great number of plants, many of which are identical with species found in the European Miocene. Amongst these plants are found many trees, such as conifers, beeches, oaks, maples, plane-trees, walnuts, magnolias, &c.,

Fig. 721. — *Platanus aceroides.* *a*, Leaf; *b*, The core of a bundle of pericarps; *c*, A single fruit or pericarp, natural size. Upper Miocene.

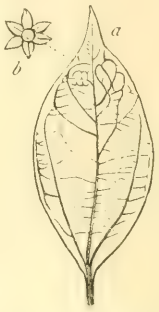

Fig. 722. — *Cinnamomum polymorphum.* *a*, Leaf; *b*, Flower. Upper Miocene.

with numerous shrubs, ferns, and other smaller plants. With regard to the Miocene flora of the Arctic regions, Sir Charles Lyell remarks that "more than thirty species of Coniferæ have been found, including several Sequoias (allied to the gigantic Wellingtonia of California), with species of *Thujopsis* and *Salisburia*, now peculiar to Japan. There are also beeches, oaks, planes, poplars, maples, walnuts, limes, and even a magnolia, two cones of which have recently been obtained, proving that this splendid evergreen not only lived but ripened its fruit within the Arctic circle. Many of the limes, planes, and oaks were large-leaved species; and both flowers and fruits, besides immense quantities of leaves, are in many cases preserved. Among the shrubs are many evergreens, as *Andromeda*, and two extinct genera, *Daphnogene* and *M'Clintockia*, with fine leathery leaves, together with hazel, blackthorn, holly, logwood, and hawthorn. A species of Zamia (*Zamites*) grew in the swamps, with *Potamogeton*, *Sparganium*, and *Menyanthes;* while ivy and vines twined around the forest-trees, and broad-leaved ferns grew beneath their shade. Even in Spitzbergen, as far north as lat. 78°

56′, no less than ninety-five species of fossil plants have been obtained, including *Taxodium* of two species, hazel, poplar, alder, beech, plane-tree, and lime. Such a vigorous growth of trees within 12° of the pole, where now a dwarf willow and a few herbaceous plants form the only vegetation, and where the ground is covered with almost perpetual snow and ice, is truly remarkable."

Taking the Miocene flora as a whole, Dr Heer concludes from his study of about 3000 plants contained in the European Miocene alone, that the Miocene plants indicate tropical or sub-tropical conditions, but that there is a striking intermixture of forms which are at present found in countries widely removed from one another. It is impossible to state with certainty how many of the Miocene plants belong to existing species, but it appears that the larger number are extinct. According to Heer, the American types of plants are most largely represented in the Miocene flora, next those of Europe and Asia, next those of Africa, and lastly those of Australia. Upon the whole, however, the Miocene flora of Europe is mostly nearly allied to the plants which we now find inhabiting the warmer parts of the United States; and this has led to the suggestion that in Miocene times the North Atlantic Ocean was dry land, and that a migration of American plants to Europe was thus permitted. This view is borne out by the fact that the Miocene plants of Europe are most nearly allied to the living plants of the eastern or Atlantic seaboard of the United States, and also by the occurrence of a rich Miocene flora in Greenland. As regards Greenland, Dr Heer has determined that the Miocene plants indicate a temperate climate in that country, with a mean annual temperature at least 30° warmer than it is at present.

The present limit of trees is the isothermal which gives the mean temperature of 50° Fahr. in July, or about the parallel of 67° N. latitude. In Miocene times, however, the limes, cypresses, and plane-trees reach the 79th degree of latitude, and the pines and poplars must have ranged even further north than this.

Pliocene Plants.—The vegetation of the Pliocene period

is, upon the whole, so closely allied to that now existing as to call for no special mention. It is worthy of notice, however, that the Pliocene flora of Europe was strikingly similar to that now existing in North America. Thus, we find in the Pliocene of Europe genera such as the Locust-trees (*Robinia*), the Honey-locusts (*Gleditschia*), the Sumach (*Rhus*), the Bald Cypress, (*Taxodium*), the Tulip-tree (*Liriodendron*), the Sweet-gum tree (*Liquidambar*), the Sour-gum tree (*Nyssa*), &c., which do not now occur in Europe, but are at present characteristic forms in the flora of temperate North America.

GLOSSARY.

ABDOMEN (Lat. *abdo*, I conceal). The posterior cavity of the body, containing the intestines and others of the viscera. In many Invertebrates there is no separation of the body-cavity into thorax and abdomen, and it is only in the higher *Annulosa* that a distinct abdomen can be said to exist.

ABERRANT (Lat. *aberro*, I wander away). Departing from the regular type.

ABNORMAL (Lat. *ab*, from; *norma*, a rule). Irregular; deviating from the ordinary standard.

ABRANCHIATE (Gr. *a*, without; *bragchia*, gill). Destitute of gills or branchiæ.

ACANTHOPTERYGII (Gr. *akantha*, spine; *pterux*, wing). A group of bony fishes with spinous rays in the front part of the dorsal fin.

ACARINA (Gr. *akari*, a mite). A division of the *Arachnida*, of which the Cheese-mite is the type.

ACEPHALOUS (Gr. *a*, without; *kephale*, head). Not possessing a distinct head.

ACETABULA (Lat. *acetabulum*, a cup). The suckers with which the cephalic processes of many *Cephalopoda* (Cuttle-fishes) are provided.

ACETABULUM. The cup-shaped socket of the hip-joint in Vertebrates.

ACRODONT (Gr. *akros*, high; *odous*, tooth). Applied to Lizards, in which the teeth are anchylosed with the summit of the jaw.

ACROGENS (Gr. *akros*, high; *gennao*, I produce). Plants which increase in height by additions made to the summit of the stem, by the union of the bases of the leaves.

ACTINOZOA (Gr. *aktin*, a ray; and *zoön*, an animal). That division of the *Cœlenterata* of which the Sea-anemones may be taken as the type.

ALVEOLI (Lat. dim. of *alvus*, belly). Applied to the sockets of the teeth.

AMBULACRA (Lat. *ambulacrum*, a place for walking). The perforated spaces or "avenues" through which are protruded the tube-feet, by means of which locomotion is effected in the *Echinodermata*.

AMBULATORY (Lat. *ambulo*, I walk). Formed for walking. Applied to a single limb, or to an entire animal.

AMMONITIDÆ. A family of Tetrabranchiate Cephalopods, so called from the resemblance of the shell of the type-genus, *Ammonites*, to the horns of the Egyptian god, Jupiter-Ammon.

Amœba (Gr. *amoibos*, changing). A species of Rhizopod, so called from the numerous changes of form which it undergoes.

Amœbiform. Resembling an *Amœba* in form.

Amorphozoa (Gr. *a*, without; *morphe*, shape; *zoön*, animal). A name sometimes used to designate the *Sponges*.

Amphibia (Gr. *amphi*, both; *bios*, life). The Frogs, Newts, and the like, which have gills when young, but can always breathe air directly when adult.

Amphicœlous (Gr. *amphi*, at both ends; *koilos*, hollow). Applied to vertebræ which are concave at both ends.

Amphipoda (Gr. *amphi*, and *pous*, a foot). An order of *Crustacea*.

Anal (Lat. *anus*, the vent). Connected with the anus, or situated near the anus.

Anarthropoda (Gr. *a*, without; *arthros*, a joint; *pous*, foot). That division of *Annulosa* animals in which there are no articulated appendages.

Anchylosis or Ankylosis (Gr. *ankulos*, crooked). The union of two bones by osseous matter, so that they become one bone, or are immovably joined together.

Angiosperms (Gr. *aggeion*, a vessel; *sperma*, seed). Plants which have their seeds enclosed in a seed-vessel.

Annelida (a Gallicised form of *Annulata*). The Ringed Worms, which form one of the divisions of the *Anarthropoda*.

Annulated. Composed of a succession of rings.

Annuloida (Lat. *annulus*, a ring; Gr. *eidos*, form). The sub-kingdom comprising the *Echinodermata* and the *Scolecida* (=*Echinozoa*).

Annulosa (Lat. *annulus*). The sub-kingdom comprising the *Anarthropoda* and the *Arthropoda* or *Articulata*, in all of which the body is more or less evidently composed of a succession of rings.

Anomodontia (Gr. *anomos*, irregular; *odous*, tooth). An extinct order of Reptiles, often called *Dicynodontia*.

Anomura (Gr. *anomos*, irregular; *oura*, tail). A tribe of Decapod *Crustacea*, of which the Hermit-crab is the type.

Anoplotheridæ (Gr. *anoplos*, unarmed; *ther*, beast). A family of Tertiary Ungulates.

Anoura (Gr, *a*, without; *oura*, tail). The order of *Amphibia* comprising the Frogs and Toads, in which the adult is destitute of a tail. Often called *Batrachia*.

Antennæ (Lat. *antenna*, a yard-arm). The jointed horns or feelers possessed by the majority of the *Articulata*.

Antennules (dim. of *Antennæ*). Applied to the smaller pair of antennæ in the *Crustacea*.

Antibrachium (Gr. *anti*, in front of; *brachion*, the arm). The fore-arm of the higher Vertebrates, composed of the *radius* and *ulna*.

Antlers. Properly the branches of the horns of the Deer tribe (*Cervidæ*), but generally applied to the entire horns.

Apiocrinidæ (Gr. *apion*, a pear; *krinon*, lily). A family of Crinoids—the "Pear-encrinites."

Aplacentalia. The section of the *Mammalia*, comprising the two divisions of the *Didelphia* and *Ornithodelphia*, in which the young is not furnished with a placenta.

Apoda (Gr. *a*, without; *podes*, feet). Applied to those fishes which have no ventral fins. Also to the footless *Cæciliæ* amongst the *Amphibia*.

Apodal. Devoid of feet.

Aptera (Gr. *a*, without; *pteron*, a wing). A division of Insects, which is characterised by the absence of wings in the adult condition.

Apterous. Devoid of wings.

Apteryx (Gr. *a*, without; *pterux*, a wing). A wingless bird of New Zealand, belonging to the order *Cursores*.

Arachnida (Gr. *arachne*, a spider). A class of the *Articulata*, comprising Spiders, Scorpions, and allied animals.

Arborescent. Branched like a tree.

Archæopteryx (Gr. *archaios*, ancient; *pterux*, wing). The singular fossil bird which alone constitutes the order of the *Saururæ*.

Arenaceous. Sandy, or composed of grains of sand.

Articulata (Lat. *articulus*, a joint). A division of the animal kingdom, comprising Insects, Centipedes, Spiders, and Crustaceans, characterised by the possession of jointed bodies or jointed limbs. The term *Arthropoda* is now more usually employed.

Artiodactyla (Gr. *artios*, even; *daktulos*, a finger or toe). A division of the hoofed quadrupeds (*Ungulata*) in which each foot has an even number of toes (two or four).

Ascidioida (Gr. *askos*, a bottle; *eidos*, a form). A synonym of *Tunicata*, a class of Molluscous animals, which have the shape, in many cases, of a two-necked bottle.

Asexual. Applied to modes of reproduction in which the sexes are not concerned.

Asiphonate. Not possessing a respiratory tube or siphon. (Applied to a division of the *Lamellibranchiate* Molluscs.)

Asteroid (Gr. *aster*, a star; and *eidos*, form). Star-shaped, or possessing radiating lobes or rays like a star-fish.

Asteroidea. An order of *Echinodermata*, comprising the Star-fishes, characterised by their rayed form.

Astomatous (Gr. *a*, without; *stoma*, mouth). Not possessing a mouth.

Atlas (Gr. the God who holds up the earth). The first vertebra of the neck, which articulates with and supports the skull.

Aves (Lat. *avis*, a bird). The class of the Birds.

Avicularium (Lat. *avicula*, dim. of *avis*, a bird). A singular appendage, often shaped like the head of a bird, found in many of the *Polyzoa*.

Axis (Gr. *axon*, a pivot). The second vertebra of the neck, upon which the skull and atlas usually rotate.

Azygous (Gr. *a*, without; *zugon*, yoke). Single; without a fellow.

Balanidæ (Gr. *balanos*, an acorn). A family of sessile *Cirripedes*, commonly called "Acorn-shells."

Baleen (Lat. *balæna*, a whale). The horny plates which occupy the palate of the true or "whalebone" Whales.

Batides (Gr. *batos*, a bramble). The family of the *Elasmobranchii* comprising the Rays.

Batrachia (Gr. *batrachos*, a frog). Often loosely applied to any of the *Am-*

phibia, but sometimes restricted to the Amphibians as a class, or to the single order of the *Anoura*.

Belemnitidæ (Gr. *belemnon*, a dart). An extinct group of Dibranchiate Cephalopods, comprising the Belemnites and their allies.

Bifid. Cleft into two parts; forked.

Bilateral. Having two symmetrical sides.

Bimana (Lat. *bis*, twice; *manus*, a hand). The order of *Mammalia* comprising Man alone.

Bipedal (Lat. *bis*, twice; *pes*, foot). Walking upon two legs.

Bivalve (Lat. *bis*, twice; *valvæ*, folding-doors). Composed of two plates or valves; applied to the shell of the *Lamellibranchiata* and *Brachiopoda*, and to the carapace of certain *Crustacea*.

Blastoidea (Gr. *blastos*, a bud; and *eidos*, form). An extinct order of *Echinodermata*, often called *Pentremites*.

Brachiopoda (Gr. *brachion*, an arm; *pous*, the foot). A class of the *Molluscoida*, often called "Lamp-shells," characterised by possessing two fleshy arms continued from the sides of the mouth.

Brachium (Gr. *brachion*, arm). Applied to the upper arm of Vertebrates.

Brachyura (Gr, *brachus*, short; *oura*, tail). A tribe of the Decapod *Crustaccans* with short tails (*i.e.*, the Crabs).

Bradypodidæ (Gr. *bradus*, slow; *podes*, feet). The family of *Edentata* comprising the Sloths.

Branchia (Gr. *bragchia*, the gill of a fish). A respiratory organ adapted to breathe air dissolved in water.

Branchiate. Possessing gills or branchiæ.

Branchifera (Gr. *bragchia*, gill; and *phero*, I carry). A division of *Gasteropodous Molluscs*, in which the respiration is aquatic, and the respiratory organs are mostly in the form of distinct gills.

Branchio-gasteropoda (=Branchifera).

Branchiopoda (Gr. *bragchia;* and *pous*, foot). A legion of *Crustacea*, in which the gills are supported by the feet.

Branchiostegal (Gr. *bragchia*, gill; *stego*, I cover). Applied to a membrane and rays by which the gills are protected in many fishes.

Bronteus (Gr. *bronté*, thunder—an epithet of Jupiter the Thunderer). A genus of Trilobites.

Brontotherium (Gr. *bronté*, thunder; *thērion*, beast). An extinct genus of Ungulate Quadrupeds.

Brontozoum (Gr. *bronté*, thunder; *zoön*, animal). A genus founded on the largest footprints of the Triassic Sandstones of Connecticut.

Bruta (Lat. *brutus*, heavy, stupid). Often used to designate the Mammalian order of the *Edentata*.

Bryozoa (Gr. *bruon*, moss; *zoön*, animal). A synonym of *Polyzoa*, a class of the *Molluscoida*.

Buccal (Lat. *bucca*, mouth or cheeks). Connected with the mouth.

Bursiform (Lat. *bursa*, a purse; *forma*, shape). Shaped like a purse; sub-spherical.

Byssiferous. Producing a byssus.

Byssus (Gr. *bussos*, flax). A term applied to the silky filaments by which the *Pinna*, the common Mussel, and certain other bivalve *Mollusca*, attach themselves to foreign objects.

CADUCIBRANCHIATE (Lat. *caducus*, falling off; Gr. *bragchia*, gill). Applied to those Amphibians in which the gills fall off before maturity is reached.

CADUCOUS. Applied to parts which fall off or are shed during the life of the animal.

CÆCAL (Lat. *cæcus*, blind). Terminating blindly, or in a closed extremity.

CÆCUM (Lat. *cæcus*). A tube which terminates blindly.

CÆSPITOSE (Lat. *cæspes*, a turf). Tufted.

CAINOZOIC. (*See* Kainozoic.)

CALAMITES (Lat. *calamus*, a reed). Extinct plants with reed-like stems, believed to be gigantic representatives of the *Equisetaceæ*.

CALCAREOUS (Lat. *calx*, lime). Composed of carbonate of lime.

CALICE. The little cup in which the polype of a coralligenous Zoophyte (*Actinozoon*) is contained.

CALYCOPHORIDÆ (Gr. *kalux*, a cup; and *phero*, I carry). An order of the Oceanic *Hydrozoa*, so called from their possessing bell-shaped swimming organs (*nectocalyces*).

CALYX (Lat. *calyx*, a cup). Applied to the cup-shaped body of *Vorticella* (*Protozoa*), or of a *Crinoid* (*Echinodermata*).

CAMPANULARIDA (Lat. *campanula*, a bell). An order of Hydroid Zoophytes.

CANINE (Lat. *canis*, a dog). The eye-tooth of Mammals, or the tooth which is placed at or close to the præmaxillary suture in the upper jaw, and the corresponding tooth in the lower jaw.

CAPITULUM (Lat. dim. of *caput*, head). Applied to the body of a Barnacle (*Lepadidæ*), from its being supported upon a stalk or peduncle.

CARAPACE. A protective shield. Applied to the upper shell of Crabs, Lobsters, and many other *Crustacea;* also to the case with which certain of the *Infusoria* are provided. Also the upper half of the immovable case in which the body of a Chelonian is protected.

CARCHARODON (Gr. *karcharos*, rough; *odous*, tooth). A genus of Sharks.

CARDIOCARPON (Gr. *kardia*, the heart; *karpos*, fruit). A genus of fossil fruit from the Coal-measures.

CARDIUM (Gr. *kardia*, the heart). The genus of Bivalve Molluscs comprising the Cockles. *Cardinia*, *Cardiola*, and *Cardita* have the same derivation.

CARINATÆ (Lat. *carina*, a keel). Applied by Huxley to all those birds in which the sternum is furnished with a median ridge or keel.

CARNIVORA (Lat. *caro*, flesh; *voro*, I devour). An order of the *Mammalia*.

CARNIVOROUS (Lat. *caro*, flesh; *voro*, I devour). Feeding upon flesh.

CARNOSE (Lat. *caro*). Fleshy.

CARPUS (Gr. *karpos*, the wrist). The small bones which intervene between the fore-arm and the metacarpus.

CATARHINA (Gr. *kata*, downwards; *rhines*, nostrils). A group of the *Quadrumana*.

CAUDAL (Lat. *cauda*, the tail). Belonging to the tail.

CAVICORNIA (Lat. *cavus*, hollow; *cornu*, a horn). The "hollow-horned" Ruminants, in which the horn consists of a central bony "horn-core" surrounded by a horny sheath.

CENTRUM (Gr. *kentron*, the point round which a circle is described by a pair of compasses). The central portion or "body" of a vertebra.

CEPHALASPIDÆ (Gr. *kephale*, head; *aspis*, shield). A family of fossil fishes.

CEPHALIC (Gr. *kephale*, head). Belonging to the head.

CEPHALO-BRANCHIATE (Gr. *kephale ;* and *bragchia,* gill). Carrying gills upon the head. Applied to a section of the *Annelida,* which, like the *Serpulæ,* have tufts of external gills placed upon the head.

CEPHALOPHORA (Gr. *kephale ;* and *phero,* I carry). Used synonymously with *Encephala,* to designate those *Mollusca* which possess a distinct head.

CEPHALOPODA (Gr. *kephale ;* and *podes,* feet). A class of the *Mollusca,* comprising the Cuttle-fishes and their allies, in which there is a series of arms ranged round the head.

CEPHALOTHORAX (Gr. *kephale ;* and *thorax,* chest). The anterior division of the body in many *Crustacea* and *Arachnida,* which is composed of the coalesced head and thorax.

CERATIOCARIS (Gr. *keras,* a horn ; *karis,* a shrimp). A genus of Phyllopod Crustaceans.

CERATITES (Gr. *keras,* a horn). A genus of *Ammonitidæ.*

CERATODUS (Gr. *keras,* a horn ; *odous,* tooth). A genus of Dipnoous fishes.

CERVICAL (Lat. *cervix,* the neck). Connected with or belonging to the region of the neck.

CERVIDÆ (Lat. *cervus,* a stag). The family of the Deer.

CESTRAPHORI (Gr. *kestra,* a weapon ; *phero,* I carry). The group of the "Cestracion Fishes," represented at the present day by the Port-Jackson Shark ; so called from their defensive spines.

CETACEA (Gr. *kētos,* a whale). The order of Mammals comprising the Whales and the Dolphins.

CETIOSAURUS (Gr. *kētos,* whale ; *saura,* lizard). A genus of Deinosaurian Reptiles.

CHEIROPTERA (Gr. *cheir,* hand ; *pteron,* wing). The Mammalian order of the Bats.

CHEIROTHERIUM (Gr. *cheir,* hand; *thērion,* beast). The generic name applied originally to the hand-shaped footprints of Labyrinthodonts.

CHEIRURUS (Gr. *cheir,* hand ; *oura,* tail). A genus of Trilobites.

CHELÆ (Gr. *chele,* a claw). The prehensile claws with which some of the limbs are terminated in certain *Crustacea,* such as the Crab, Lobster, &c.

CHELATE. Possessing chelæ ; applied to a limb.

CHELICERÆ (Gr. *chele,* a claw ; and *keras,* a horn). The prehensile claws of the Scorpion, supposed to be homologous with antennæ.

CHELONIA (Gr. *chelone,* a tortoise). The order of Reptiles comprising the Tortoises and Turtles.

CHELONOBATRACHIA (Gr. *chelone,* a tortoise ; *batrachos,* a frog). Sometimes applied to the Amphibian order of the *Anoura* (Frogs and Toads).

CHILOGNATHA (Gr. *cheilos,* a lip ; and *gnathos,* a jaw). An order of the *Myriapoda.*

CHILOPODA (Gr. *cheilos ;* and *podes,* feet). An order of the *Myriapoda.*

CHITINE (Gr. *chiton,* a coat). The peculiar chemical principle, nearly allied to horn, which forms the exoskeleton in many Invertebrate Animals, especially in the *Arthropoda* (*Crustacea, Insecta,* &c.)

CIRRI (Lat. *cirrus,* a curl). Tendril-like appendages, such as the feet of Barnacles and Acorn-shells (*Cirripedes*), the lateral processes on the arms of *Brachiopoda,* &c.

CIRRIFEROUS or CIRRIGEROUS. Carrying cirri.

Cirripedia, Cirrhipedia or Cirrhopoda (Lat. *cirrus*, a curl; and *pes*, a foot). A sub-class of *Crustacea* with curled jointed feet.

Cladocera (Gr. *klados*, a branch; *keras*, a horn). An order of *Crustacea* with branched antennæ.

Clavate (Lat. *clavus*, a club). Club-shaped.

Clavicle (Lat. *clavicula*, a little key). The "collar-bone," forming one of the elements of the pectoral arch of Vertebrates.

Cloaca (Lat. a sink). The cavity into which the intestinal canal and the ducts of the generative and urinary organs open in common, in some Invertebrates (*e.g.*, in Insects), and also in many Vertebrate animals.

Clypeiform (Lat. *clypeus*, a shield; and *forma*, shape). Shield-shaped; applied, for example, to the carapace of the King-crab.

Coccosteus (Gr. *kokkos*, berry; *osteon*, bone). A genus of Ganoid Fishes.

Cochliodus (Gr. *kochlion*, a snail-shell; *odous*, tooth). A genus of Cestraciont Fishes.

Cœlenterata (Gr. *koilos*, hollow; *enteron*, the bowel). The sub-kingdom which comprises the *Hydrozoa* and *Actinozoa*. Proposed by Frey and Leuckhart in place of the old term *Radiata*, which included other animals as well.

Cœnenchyma (Gr. *koinos*, common; *enchuma*, tissue, literally an infusion). The common calcareous tissue which unites together the various corallites of a compound corallum.

Cœnœcium (Gr. *koinos*, common; *oikos*, house.) The entire dermal system of any *Polyzoön:* employed in place of the terms polyzoary or polypidom.

Cœnosarc (Gr. *koinos*, common; *sarx*, flesh). The common organised medium by which the separate polypites of a compound *Hydrozoön* are connected together.

Coleoptera (Gr. *koleos*, a sheath; *pteron*, wing). The order of Insects (Beetles) in which the anterior pair of wings are hardened, and serve as protective cases for the posterior pair of membranous wings.

Colubrina (Lat. *coluber*, a snake). A division of the *Ophidia*.

Columbacei (Lat. *columba*, a dove). The division of Rasorial birds comprising the Doves and Pigeons.

Columella (Lat. dim. of *columna*, a column). In Conchology, the central axis round which the whorls of a spiral univalve are wound. Amongst the *Actinozoa*, it is the central axis or pillar which is found in the centre of the thecæ of many corals.

Column. Applied to the cylindrical body of a Sea-anemone (*Actinia*); also to the jointed stem or peduncle of the stalked *Crinoids*.

Conchifera (Lat. *concha*, a shell; *fero*, I carry). Shell-fish. Applied in a restricted sense to the bivalve Molluscs, and used as a synonym for *Lamellibranchiata*.

Condyle (Gr. *kondulos*, a knuckle). The surface by which one bone articulates with another. Applied especially to the articular surface or surfaces by which the skull articulates with the vertebral column.

Conirostres (Lat. *conus*, a cone; *rostrum*, a beak). The division of Perching Birds with conical beaks.

Copepoda (Gr. *kope*, an oar; *podes*, feet). An order of *Crustacea*.

Coracoid (Gr. *korax*, a crow; *eidos*, form). One of the bones which enters into the composition of the pectoral arch in the *Vertebrata*. In most Mammals

it is a mere process of the scapula, having, in Man, some resemblance in shape to the beak of a crow.

Coralligenous. Producing a corallum.

Corallite. The corallum secreted by an *Actinozoön* which consists of a single polype; or the portion of a composite corallum which belongs to, and is secreted by, an individual polype.

Corallum (from the Latin for Red Coral). The hard structures deposited in, or by, the tissues of an *Actinozoön*—commonly called a "coral."

Coriaceous (Lat. *corium*, hide). Leathery.

Corynida (Gr. *korune*, a club). A group of the Hydroid Zoophytes, so called from their sometimes possessing clubbed tentacles.

Costæ (Lat. *costa*, a rib). Applied amongst the *Crinoidea* to designate the rows of plates which succeed the inferior or basal portion of the cup (pelvis). Amongst the *Corals* the "costæ" are vertical ridges which occur on the outer surface of the theca, and mark the position of the septa within.

Costal (Lat. *costa*, a rib). Connected with the ribs.

Cranium (Gr. *kranion*, the skull). The bony or cartilaginous case in which the brain is contained.

Crinoidea (Gr. *krinon*, a lily; *eidos*, form). An order of *Echinodermata*, comprising forms which are usually stalked, and sometimes resemble lilies in shape.

Crocodilia (Gr. *krokodeilos*, a crocodile). An order of Reptiles.

Crossopterygidæ (Gr. *krossos*, a fringe; *pterux*, a fin). A sub-order of Ganoids in which the paired fins possess a central lobe.

Crustacea (Lat. *crusta*, a crust). A class of Articulate animals, comprising Crabs, Lobsters, &c., characterised by the possession of a hard shell or crust, which they cast periodically.

Cryptogams (Gr. *kruptos*, concealed; *gamos*, marriage). A division of plants in which the organs of reproduction are obscure and there are no true flowers.

Ctenoid (Gr. *kteis*, a comb; *eidos*, form). Applied to those scales of fishes, the hinder margins of which are fringed with spines or comb-like projections.

Ctenophora (Gr. *kteis*, a comb; and *phero*, I carry). An order of *Actinozoa*, comprising oceanic creatures, which swim by means of "ctenophores," or bands of cilia arranged in comb-like plates.

Cursores (Lat. *curro*, I run). An order of *Aves*, comprising birds destitute of the power of flight, but formed for running vigorously (*e.g.*, the Ostrich and Emeu).

Cuspidate. Furnished with small pointed eminences or "cusps."

Cuticle (Lat. *cuticula*, dim. of *cutis*, skin). The pellicle which forms the outer layer of the body amongst the *Infusoria*. The outer layer of the integument generally.

Cycloid (Gr. *kuklos*, a circle; *eidos*, form). Applied to those scales of fishes which have a regularly circular or elliptical outline with an even margin.

Cyclostomi (Gr. *kuklos;* and *stoma*, mouth). Sometimes used to designate the Hag-fishes and Lampreys, forming the order *Marsipobranchii*.

Cyst (Gr. *kustis*, a bladder or bag). A sac or vesicle.

Cystoidea (Gr. *kustis*, a bladder; and *eidos*, form). An extinct order of *Echinodermata*.

DECAPODA (Gr. *deka*, ten; *podes*, feet). The division of *Crustacea* which have ten ambulatory feet; also the family of Cuttle-fishes, in which there are ten arms or cephalic processes.

DECIDUOUS (Lat. *decido*, I fall off). Applied to parts which fall off or are shed during the life of the animal.

DECOLLATED (Lat. *decollo*, I behead). Applied to univalve shells, the apex of which falls off in the course of growth.

DEINOSAURIA (Gr. *deinos*, terrible; *saura*, lizard). An extinct order of Reptiles.

DENDRIFORM, DENDRITIC, DENDROID (Gr. *dendron*, a tree). Branched like a tree, arborescent.

DERMAL (Gr. *derma*, skin). Belonging to the integument.

DESMIDIÆ. Minute fresh-water plants, of a green colour, without a siliceous epidermis.

DEXTRAL (Lat. *dextra*, the right hand). Right-handed. Applied to the direction of the spiral in the greater number of univalve shells.

DIAPHRAGM (Gr. *diaphragma*, a partition). The "midriff" or the muscle which in *Mammalia* forms a partition between the cavities of the thorax and abdomen.

DIASTEMA (Gr. *dia*, apart; *histemi*, I place). A gap or interval, especially between teeth.

DIATOMACEÆ (Gr. *diatemno*, I sever). An order of minute plants, which are provided with siliceous envelopes.

DIBRANCHIATA (Gr. *dis*, twice; *bragchia*, gill). The order of *Cephalopoda* (comprising the Cuttle-fishes, &c.) in which only two gills are present.

DICYNODONTIA (Gr. *dis*, twice; *kuon*, dog; *odous*, tooth). An extinct order of Reptiles.

DIDELPHIA (Gr. *dis*, twice; *delphus*, womb). The subdivision of Mammals comprising the Marsupials.

DIGIT (Lat. *digitus*, a finger). A finger or toe.

DIGITIGRADA (Lat. *digitus*; *gradior*, I walk). A subdivision of the *Carnivora*.

DIGITIGRADE. Walking upon the tips of the toes, and not upon the soles of the feet.

DIMYARY (Gr. *dis*, twice; *muon*, muscle). Applied to those bivalve Molluscs (*Lamellibranchiata*) in which the shell is closed by two adductor muscles.

DINICHTHYS (Gr. *deinos*, terrible; *ichthus*, fish). An extinct genus of Fishes.

DINOCERAS (Gr. *deinos*, terrible; *keras*, horn). An extinct genus of Mammals.

DINOPHIS (Gr. *deinos*, terrible; *ophis*, snake). An extinct genus of Snakes.

DINORNIS (Gr. *deinos*, terrible; *ornis*, bird). An extinct genus of Birds.

DIPHYODONT (Gr. *dis*, twice; *phuo*, I generate; *odous*, tooth). Applied to those Mammals which have two sets of teeth.

DIPNOI (Gr. *dis*, twice; *pnoe*, breath). The order of Fishes represented by the *Lepidosiren*.

DIPTERA (Gr. *dis*, twice; *pteron*, wing). An order of Insects characterised by the possession of two wings.

DISCOID (Gr. *diskos*, a quoit; *eidos*, form). Shaped like a round plate or quoit.

DISCOPHORA (Gr. *diskos*, a quoit; *phero*, I carry). This term is applied to the *Medusæ*, or Jelly-fishes, from their form; and it is sometimes used to designate

the order of the Leeches (*Hirudinea*), from the suctorial discs which these animals possess.

Dissepiments (Lat. *dissepio,* I partition off). Partitions. Used in a restricted sense to designate certain imperfect transverse partitions, which grow from the septa of many corals.

Distal. Applied to the quickly-growing end of the hydrosoma of a *Hydrozoön;* the opposite, or "proximal," extremity growing less rapidly, and being the end by which the organism is fixed, when attached at all. Applied generally to that extremity of a limb, muscle, or bone, which is furthest removed from the trunk.

Diurnal (Lat. *dies,* day). Applied to animals which are active during the day.

Dorsal (Lat. *dorsum,* back). Connected with the back.

Dorsibranchiate (Lat. *dorsum,* the back; Gr. *bragchia,* gill). Having external gills attached to the back; applied to certain *Annelides* and *Molluscs.* The term is of mongrel composition, and "notobranchiate" is more correctly employed.

Echinodermata (Gr. *echinos;* and *derma,* skin). A class of animals comprising the Sea-urchins, Star-fishes, and others, most of which have spiny skins.

Echinoidea (Gr. *echinos;* and *eidos,* form). An order of *Echinodermata,* comprising the Sea-urchins.

Echinulate. Possessing spines.

Ectocyst (Gr. *ektos,* outside; *kustis,* a bladder). The external investment of the cœnœcium of a *Polyzoön.*

Ectoderm (Gr. *ektos;* and *derma,* skin). The external integumentary layer of the *Cœlenterata.*

Edentata (Lat. *e,* without; *dens,* tooth). An order of *Mammalia* often called *Bruta.*

Edentulous. Toothless, without any dental apparatus. Applied to the mouth of any animal, or to the hinge of the bivalve Molluscs.

Edriophthalmata (Gr. *hedraios,* sitting; *ophthalmos,* eye). The division of *Crustacea* in which the eyes are sessile, and are not supported upon stalks.

Elasmobranchii (Gr. *elasma,* a plate; *bragchia,* gill). An order of Fishes, including the Sharks and Rays.

Elytra (Gr. *elutron,* a sheath). The chitinous anterior pair of wings in Beetles, which form cases for the posterior membranous wings. Also applied to the scales or plates on the back of the Sea-mouse (*Aphrodite*).

Embryo (Gr. *en,* in; *bruo,* I swell). The earliest stage at which the young animal is recognisable in the impregnated ovum.

Enaliosauria (Gr. *enalios,* marine; *saura,* lizard). Sometimes employed as a common term to designate the extinct Reptilian orders of the *Ichthyosauria* and *Plesiosauria.*

Encephalous (Gr. *en,* in; *kephale,* the head). Possessing a distinct head. Usually applied to all the *Mollusca* proper, except the *Lamellibranchiata.*

Endocyst (Gr. *endon,* within; *kustis,* a bag). The inner membrane or integumentary layer of a *Polyzoön.* In *Cristatella,* where there is no "ectocyst," the endocyst constitutes the entire integument.

ENDODERM (Gr. *endon;* and *derma*, skin). The inner integumentary layer of the *Cœlenterata*.

ENDOPODITE (Gr. *endon;* and *pous*, foot). The inner of the two secondary joints into which the typical limb of a *Crustacean* is divided.

ENDOSKELETON (Gr. *endon;* and *skeletos*, dry). The internal hard structures, such as bones, which serve for the attachment of muscles, or the protection of organs, and which are not a mere hardening of the integument.

ENSIFORM (Lat. *ensis*, a sword; *forma*, shape). Sword-shaped.

ENTOMOPHAGA (Gr. *entoma*, insects; *phago*, I eat). A section of the Marsupialia.

ENTOMOSTRACA (Gr. *entoma*, insects; *ostrakon*, a shell). Literally Shelled Insects; applied to a division of *Crustacea*.

ENTOZOA (Gr. *entos*, within; *zoön*, animal). Animals which are parasitic in the interior of other animals.

EOCENE (Gr. *eos*, dawn; *kainos*, new or recent). The lowest division of the Tertiary rocks, in which species of existing shells are to a small extent represented.

EPIDERMIS (Gr. *epi*, upon; *derma*, the true skin). The outer non-vascular layer of the skin, often called the scarf-skin or *cuticle*.

EPIMERA (Gr. *epi*, upon; *mēron*, thigh). The lateral pieces of the dorsal arc of the somite of a *Crustacean*.

EPIPODIA (Gr. *epi*, upon; *pous*, the foot). Muscular lobes developed from the lateral and upper surfaces of the "foot" of some *Molluscs*.

EPIPODITE (Gr. *epi*, upon; *pous*, foot). A process developed upon the basal joint, or "protopodite," of some of the limbs of certain *Crustacea*.

EPISTERNA (Gr. *epi*, upon; *sternon*, the breast-bone). The lateral pieces of the inferior or ventral arc of the somite of a *Crustacean*.

EPISTOME (Gr. *epi;* and *stoma*, mouth). A valve-like organ which arches over the mouth in certain of the *Polyzoa*.

EPITHECA (Gr. *epi;* and *theke*, a sheath). A continuous layer surrounding the thecæ in some Corals externally.

EPIZOA (Gr. *epi*, upon; *zoön*, animal). Animals which are parasitic upon other animals. In a restricted sense, a division of *Crustacea* which are parasitic upon fishes.

EQUILATERAL (Lat. *æquus*, equal; *latus*, side). Having its sides equal. Usually applied to the shells of the *Brachiopoda*. When applied to the spiral shells of the *Foraminifera*, it means that all the convolutions of the shell lie in the same plane.

EQUISETACEÆ (Lat. *equus*, horse; *seta*, bristle). A group of Cryptogamous plants, commonly known as "Horse-tails."

EQUIVALVE (Lat. *æquus*, equal; *valvæ*, folding-doors). Applied to shells which are composed of two equal pieces or valves.

ERRANTIA (Lat. *erro*, I wander). An order of *Annelida*, often called *Nereidea*, distinguished by their great locomotive powers.

EURYPTERIDA (Gr. *eurus*, broad; *pteron*, wing). An extinct sub-order of *Crustacea*.

EXOPODITE (Gr. *exo*, outside; *pous*, foot). The outer of the two secondary joints into which the typical limb of a *Crustacean* is divided.

EXOSKELETON (Gr. *exo*, outside; *skeletos*, dry). The external skeleton, which is constituted by a hardening of the integument, and is often called a "dermoskeleton."

Fasciculated (Lat. *fasciculus*, a bundle). Arranged in bundles.

Fauna (Lat. *Fauni*, the rural deities of the Romans). The general assemblage of the animals of any region or district.

Femur. The thigh-bone, intervening between the pelvis and the bones of the leg proper (*tibia* and *fibula*).

Fibula (Lat. a brooch). The outermost of the two bones of the leg in the higher *Vertebrata;* corresponding to the *ulna* of the fore-arm.

Filices (Lat. *filix*, a fern). The order of Cryptogamic plants comprising the Ferns.

Filiform (Lat. *filum*, a thread; *forma*, shape). Thread-shaped.

Fission (Lat. *findo*, I cleave). Multiplication by means of a process of self-division.

Fissiparous (Lat. *findo;* and *pario*, I produce). Giving origin to fresh structures by a process of fission.

Flora (Lat. *Flora*, the goddess of flowers). The general assemblage of the plants of any region or district.

Foot-jaws. The limbs of *Crustacea*, which are modified to subserve mastication.

Foot-secretion. The term applied by Mr Dana to the sclerobasic corallum of certain *Actinozoa*.

Foot-tubercles. The unarticulated appendages of the *Annelida*, often called "parapodia."

Foraminifera (Lat. *foramen*, an aperture; *fero*, I carry). An order of *Protozoa*, usually characterised by the possession of a shell perforated by numerous pseudopodial apertures.

Frugivorous (Lat. *frux*, fruit; *voro*, I devour). Living upon fruits.

Fucoids (Lat. *fucus*, sea-weed; Gr. *eidos*, likeness). Fossils, often of an obscure nature, believed to be the remains of sea-weeds.

Furculum or Furcula (Lat. dim. of *furca*, a fork). The "merry-thought" of birds, or the V-shaped bone formed by the united clavicles.

Fusiform (Lat. *fusus*, a spindle; and *forma*, shape). Spindle-shaped, or pointed at both ends.

Gallinacei (Lat. *gallina*, a fowl). Sometimes applied to the whole order of the Rasorial Birds, but properly restricted to that section of the order of which the common Fowl is a typical example.

Ganglion (Gr. *gagglion*, a knot). A mass of nervous matter containing nerve-cells, and giving origin to nerve-fibres.

Ganoid (Gr. *ganos*, splendour, brightness). Applied to those scales or plates which are composed of an inferior layer of true bone covered by a superior layer of polished enamel.

Ganoidei. An order of Fishes.

Gasteropoda (Gr. *gaster*, stomach; *pous*, foot). The class of the *Mollusca* comprising the ordinary Univalves, in which locomotion is usually effected by a muscular expansion of the under surface of the body (the "foot").

Gemmæ (Lat. *gemma*, a bud). The buds produced by any animal, whether detached or not.

Gemmation. The process of producing new structures by budding.

Gemmiparous (Lat. *gemma*, a bud; *pario*, I produce). Giving origin to new structures by a process of budding.

GEPHYREA (Gr. *gephura*, a bridge). A class of the *Anarthropoda*, comprising the Spoon-worms (*Sipunculus*) and their allies.

GIZZARD. A muscular division of the stomach in Birds, Insects, &c.

GLADIUS (Lat. a sword). Applied to the horny endoskeleton or "pen" of certain Cuttle-fishes.

GLENOID (Gr. *glene*, a cavity; *eidos*, form). A shallow cavity; applied especially to the shallow articular cavity in the shoulder-blade to which the head of the humerus is jointed.

GRALLATORES (Lat. *grallæ*, stilts). The order of the long-legged Wading Birds.

GRAPTOLITIDÆ (Gr. *grapho*, I write; *lithos*, stone). An extinct sub-class of the *Hydrozoa*.

GREGARINIDA (Lat. *gregarius*, occurring in numbers together). A class of the *Protozoa*.

GUARD. The cylindrical fibrous sheath with which the internal chambered shell (phragmacone) of a *Belemnite* is protected.

GYMNOLÆMATA (Gr. *gumnos*, naked; *laimos*, the throat). An order of the *Polyzoa* in which the mouth is devoid of the valvular structure known as the "epistome."

GYMNOPHIONA (Gr. *gumnos*, naked; *ophis*, a snake). The order of the *Amphibia* comprising the snake-like *Cæciliæ*.

GYMNOPHTHALMATA (Gr. *gumnos;* and *ophthalmos*, the eye). Applied by Edward Forbes to those *Medusæ* in which the eye-specks at the margin of the disc are unprotected. The division is now abandoned.

GYMNOSOMATA (Gr. *gumnos;* and *soma*, the body). The order of *Pteropoda* in which the body is not protected by a shell.

HALLUX (Lat. *allex*, the thumb or great toe). The innermost of the five digits which normally compose the *hind* foot of a Vertebrate animal. In man, the great toe.

HEMIPTERA (Gr. *hemi*, half; and *pteron*, wing). An order of Insects in which the anterior wings are sometimes "hemelytra."

HERMAPHRODITE (Gr. *Hermes*, Mercury; *Aphrodite*, Venus). Possessing the organs of both sexes combined.

HETEROCERCAL (Gr. *heteros*, diverse; *kerkos*, tail). Applied to the tail of Fishes when it is unsymmetrical, or composed of two unequal lobes.

HETEROPODA (Gr. *heteros*, diverse; *podes*, feet). An aberrant group of the Gasteropods, in which the foot is modified so as to form a swimming organ.

HIRUDINEA (Lat. *hirudo*, a horse-leech). The order of *Annelida* comprising the Leeches.

HISTOLOGY (Gr. *histos*, a web; *logos*, a discourse). The study of the tissues, more especially of the minuter elements of the body.

HOLOCEPHALI (Gr. *holos*, whole; *kephale*, head). A sub-order of the *Elasmobranchii* comprising the *Chimæræ*.

HOLOSTOMATA (Gr. *holos*, whole; *stoma*, mouth). A division of *Gasteropodous Molluscs*, in which the aperture of the shell is rounded, or "entire."

HOLOTHUROIDEA (Gr. *holothourion;* and *eidos*, form). An order of *Echinodermata* comprising the Trepangs.

HOMOCERCAL (Gr. *homos*, same; *kerkos*, tail). Applied to the tail of Fishes when it is symmetrical, or composed of two equal lobes.

Homologous (Gr. *homos;* and *logos*, a discourse). Applied to parts which are constructed upon the same fundamental plan.

Humerus. The bone of the upper arm (*brachium*) in the Vertebrates.

Hyaline (Gr. *hualos*, crystal). Crystalline or glassy.

Hybodonts (Gr. *hubos*, curved; *odous*, tooth). A group of Fishes of which *Hybodus* is the type-genus.

Hydroida (Gr. *hudra;* and *eidos*, form). The sub-class of the *Hydrozoa*, which comprises the animals most nearly allied to the *Hydra*.

Hydrotheca (Gr. *hudra;* and *theke*, a case). The little chitinous cups in which the polypites of the *Sertularida* and *Campanularida* are protected.

Hydrozoa (Gr. *hudra;* and *zoön*, animal). The class of the *Cœlenterata* which comprises animals constructed after the type of the *Hydra*.

Hymenoptera (Gr. *humen*, a membrane; *pteron*, a wing). An order of Insects (comprising, Bees, Ants, &c.) characterised by the possession of four membranous wings.

Hyoid (Gr. *U; eidos*, form). The bone which supports the tongue in Vertebrates, and derives its name from its resemblance in man to the Greek letter U.

Hypostome (Gr. *hupo*, under; *stoma*, mouth). The upper lip, or "labrum," of certain *Crustacea* (*e.g.*, Trilobites).

Hyracoidea (Gr. *hurax*, a shrew; *eidos*, form). An order of the *Mammalia* constituted for the reception of the single genus *Hyrax*.

Ichthyodorulite (Gr. *ichthus*, fish; *dorus*, spear; *lithos*, stone). The fossil fin-spines of Fishes.

Ichthyomorpha (Gr. *ichthus; morphe*, shape). An order of Amphibians, often called *Urodela*, comprising the fish-like Newts, &c.

Ichthyophthira (Gr. *ichthus; phtheir*, a louse). An order of *Crustacea* comprising animals which are parasitic upon Fishes.

Ichthyopsida (Gr. *ichthus; opsis*, appearance). The primary division of *Vertebrata*, comprising the Fishes and Amphibia. Often spoken of as the *Branchiate Vertebrata*.

Ichthyopterygia (Gr. *ichthus; pterux*, wing). An extinct order of Reptiles.

Ichthyosauria (Gr. *ichthus; saura*, lizard. Synonymous with *Ichthyopterygia*.

Ilium. The haunch-bone, one of the bones of the pelvic arch in the higher Vertebrates.

Imago (Lat. an image or apparition). The perfect insect, after it has undergone its metamorphoses.

Imbricated. Applied to scales or plates which overlap one another like tiles.

Incisor (Lat. *incido*, I cut). The cutting teeth fixed in the intermaxillary bones of the *Mammalia*, and the corresponding teeth in the lower jaw.

Inequilateral. Having the two sides unequal, as in the case of the shells of the ordinary Bivalves (*Lamellibranchiata*). When applied to the shells of the *Foraminifera*, it implies that the convolutions of the shell do not lie in the same plane, but are obliquely wound round an axis.

Inequivalve. Composed of two unequal pieces or valves.

Infundibulum (Lat. for funnel). The tube formed by the coalescence or apposition of the epipodia in the *Cephalopoda*. Commonly termed the "funnel," or "siphon."

INFUSORIA (Lat. *infusum*, an infusion). A class of *Protozoa*, so called because they are often developed in organic infusions.

INOPERCULATA (Lat. *in*, without; *operculum*, a lid). The division of pulmonate *Gasteropoda* in which there is no shelly or horny plate (operculum) by which the shell is closed when the animal is withdrawn within it.

INSECTA (Lat. *insecо*, I cut into). The class of Articulate animals commonly known as Insects.

INSECTIVORA (Lat. *insectum*, an insect; *voro*, I devour). An order of Mammals.

INSECTIVOROUS. Living upon Insects.

INSESSORES (Lat. *insedeo*, I sit upon). The order of the Perching Birds, often called *Passeres*.

INTERAMBULACRA. The rows of plates in an *Echinoderm* which are not perforated for the emission of the "tube-feet."

INTERMAXILLÆ, or PRÆMAXILLÆ. The two bones which are situated between the two superior maxillæ in *Vertebrata*. In man, and some monkeys, the præmaxillæ anchylose with the maxillæ, so as to be irrecognisable in the adult.

INVERTEBRATA (Lat. *in*, without; *vertebra*, a bone of the back). Animals without a spinal column or backbone.

ISCHIUM (Gr. *ischion*, the hip). One of the bones of the pelvic arch in Vertebrates.

ISOPODA (Gr. *isos*, equal; *podes*, feet). An order of *Crustacea* in which the feet are like one another and equal.

JUGULAR (Lat. *jugulum*, the throat). Connected with, or placed upon, the throat. Applied to the ventral fins of fishes when they are placed beneath or in advance of the pectorals.

KAINOZOIC (Gr. *kainos*, recent; *zoe*, life). The Tertiary period in Geology, comprising those formations in which the organic remains approximate more or less closely to the existing fauna and flora.

KERATODE (Gr. *keras*, horn; *eidos*, form). The horny substance of which the skeleton of many sponges is made up.

KERATOSA. The division of Sponges in which the skeleton is composed of keratode.

LABIUM (Lat. for lip). Restricted to the lower lip of Articulate animals.

LABRUM (Lat. for lip). Restricted to the upper lip of Articulate animals.

LABYRINTHODONTIA (Gr. *laburinthos*, a labyrinth; *odous*, tooth). An extinct order of *Amphibia*, so called from the complex microscopic structure of the teeth.

LACERTILIA (Lat. *lacerta*, a lizard). An order of *Reptilia* comprising the Lizards and Slow-worms.

LÆMODIPODA (Gr. *laimos*, throat; *dis*, twice; *podes*, feet). An order of *Crustacea*, so called because they have two feet placed far forwards, as it were under the throat.

LAMELLIBRANCHIATA (Lat. *lamella*, a plate; Gr. *bragchia*, gill). The class of *Mollusca*, comprising the ordinary Bivalves, characterised by the possession of lamellar gills.

Lamellirostres (Lat. *lamella*, a plate; *rostrum*, beak). The flat-billed Swimming Birds (*Natatores*), such as Ducks, Geese, Swans, &c.

Larva (Lat. a mask). The insect in its first stage after its emergence from the egg, when it is usually very different from the adult.

Larynx. The upper part of the windpipe, forming a cavity with appropriate muscles and cartilages, situated beneath the hyoid bone, and concerned in Mammals in the production of vocal sounds.

Lenticular (Lat. *lens*, a bean). Shaped like a biconvex lens.

Lepidodendron (Gr. *lepis*, a scale; *dendron*, a tree). A genus of extinct plants, so named from the scale-like scars upon the stem left by the falling off of the leaves.

Lepidoptera (Gr. *lepis*, a scale; *pteron*, a wing). An order of Insects, comprising Butterflies and Moths, characterised by possessing four wings which are usually covered with minute scales.

Lepidota (Gr. *lepis*, a scale). Formerly applied to the order *Dipnoi*, containing the Mud-fishes (*Lepidosiren*).

Leptocardia (Gr. *leptos*, slender, small; *cardia*, heart). The name given by Müller to the order of Fishes comprising the Lancelet, now called *Pharyngobranchii*.

Lophophore (Gr. *lophos*, a crest; and *phero*, I carry). The disc or stage upon which the tentacles of the *Polyzoa* are borne.

Lophyropoda (Gr. *lophouros*, having stiff hairs; and *podes*, feet). A section of *Crustacea*.

Loricata (Lat. *lorica*, a cuirass). The division of Reptiles comprising the *Chelonia* and *Crocodilia*, in which bony plates are developed in the skin (*derma*).

Lucernarida (Lat. *lucerna*, a lamp). An order of the *Hydrozoa*.

Lumbar (Lat. *lumbus*, loin). Connected with the loins.

Lunate (Lat. *luna*, moon). Crescentic in shape.

Lycopodiaceæ (Gr. *lupos*, a wolf; *pous*, foot). The group of Cryptogamic plants generally known as "Club-mosses."

Macrura (Gr. *makros*, long; *oura*, tail). A tribe of Decapod *Crustaceans* with long tails (*e.g.*, the Lobster, Shrimp, &c.)

Madreporiform. Perforated with small holes, like a coral; applied to the tubercle by which the ambulacral system of the *Echinoderms* mostly communicates with the exterior.

Malacostraca (Gr. *malakos*, soft; *ostrakon*, shell). A division of *Crustacea*. Originally applied by Aristotle to the entire class *Crustacea*, because their shells were softer than those of the *Mollusca*.

Mammalia (Lat. *mamma*, the breast). The class of Vertebrate animals which suckle their young.

Mandible (Lat. *mandibulum*, a jaw). The upper pair of jaws in Insects; also applied to one of the pairs of jaws in *Crustacea* and Spiders, to the beak of Cephalopods, the lower jaw of Vertebrates, &c.

Mantle. The external integument of most of the Mollusca, which is largely developed, and forms a cloak in which the viscera are protected. Technically called the "pallium."

Manus (Lat. the hand). The hand or fore-foot of the higher Vertebrates.

MARSIPOBRANCHII (Gr. *marsipos*, a pouch; *bragchia*, gill). The order of Fishes comprising the Hag-fishes and Lampreys, with pouch-like gills.

MARSUPIALIA (Lat. *marsupium*, a pouch). An order of Mammals in which the females mostly have an abdominal pouch in which the young are carried.

MASTICATORY (Lat. *mastico*, I chew). Applied to parts adapted for chewing.

MAXILLÆ (Lat. jaws). The inferior pair or pairs of jaws in the *Arthropoda* (Insects, Crustacea, &c). The upper jaw-bones of Vertebrates.

MAXILLIPEDES (Lat. *maxillæ*, jaws; *pes*, the foot). The limbs in *Crustacea* and *Myriapoda*, which are converted into masticatory organs, and are commonly called "foot-jaws."

MEDULLA (Lat. marrow). Applied to the marrow of bones; or to the spinal cord, with or without the adjective "*spinalis*."

MEDUSÆ. An order of *Hydrozoa*, commonly known as Jelly-fishes (*Discophora*, or *Acalephæ*), so called because of the resemblance of their tentacles to the snaky hair of the Medusa. Many *Medusæ* are now known to be merely the gonophores of other *Hydrozoa*.

MEGALONYX (Gr. *megas*, great; *onux*, nail). An extinct genus of Edentate Mammals.

MEGALOSAURUS (Gr. *megas*, great; *saura*, lizard). A genus of Deinosaurian Reptiles.

MEGATHERIUM (Gr. *megas*, great; *thērion*, beast). An extinct genus of Edentata.

MEROSTOMATA (Gr. *mēron*, thigh; *stoma*, mouth). An order of *Crustacea* in which the appendages which are placed round the mouth, and which officiate as jaws, have their free extremities developed into walking or prehensile organs.

MESENTERIES (Gr. *mesos*, intermediate; *enteron*, intestine). In a restricted sense, the vertical plates which divide the somatic cavity of a Sea-anemone (*Actinia*) into chambers.

MESOPODIUM (Gr. *mesos*, middle; *pous*, foot). The middle portion of the "foot" of Molluscs.

MESOSTERNUM (Gr. *mesos*, intermediate; *sternon*, the breast-bone). The middle portion of the sternum, intervening between the attachment of the second pair of ribs and the xiphoid cartilage (*xiphisternum*).

MESOTHORAX (Gr. *mesos*; and *thorax*, the chest). The middle ring of the thorax in Insects.

MESOZOIC (Gr. *mesos*; and *zoe*, life). The Secondary period in Geology.

METACARPUS (Gr. *meta*, after; *karpos*, the wrist). The bones which form the "root of the hand," and intervene between the wrist and the fingers.

METAMORPHOSIS (Gr. *meta*, implying change; *morphe*, shape). The changes of form which certain animals undergo in passing from their younger to their fully-grown condition.

METAPODIUM (Gr. *meta*, after; *pous*, the foot). The posterior lobe of the foot in *Mollusca*; often called the "operculigerous lobe," because it develops the operculum when this structure is present.

METASTOMA (Gr. *meta*, after; *stoma*, mouth). The plate which closes the mouth posteriorly in the *Crustacea*.

METATARSUS (Gr. *meta*, after; *tarsos*, the instep). The bones which intervene between the bones of the ankle (*tarsus*) and the digits in the hind-foot of the higher Vertebrates.

Metathorax (Gr. *meta*, after; *thorax*, the chest). The posterior ring of the thorax in Insects.

Microlestes (Gr. *mikros*, little; *lestes*, thief). An extinct genus of Triassic Mammals.

Millepora (Lat. *mille*, one thousand; *porus*, a pore). A genus of "Hydrocorallines."

Miocene (Gr. *meion*, less; *kainos*, new). The Middle Tertiary period.

Molars (Lat. *mola*, a mill). The "grinders" in man, or the teeth in diphyodont Mammals which are not preceded by milk-teeth.

Mollusca (Lat. *mollis*, soft). The sub-kingdom which includes the Shell-fish proper, the *Polyzoa*, the *Tunicata*, and the Lamp-shells; so called from the generally soft nature of their bodies.

Molluscoida (*Mollusca*; Gr. *eidos*, form). The lower division of the *Mollusca*, comprising the *Polyzoa*, *Tunicata*, and *Brachiopoda*.

Monodelphia (Gr. *monos*, single; *delphus*, womb). The division of *Mammalia* in which the uterus is single.

Monomyary (Gr. *monos*, single; *muon*, muscle). Applied to those Bivalves (*Lamellibranchiata*) in which the shell is closed by a single adductor muscle.

Monophyodont (Gr. *monos*; *phuo*, I generate; *odous*, tooth). Applied to those Mammals in which only a single set of teeth is ever developed.

Monothalamous (Gr. *monos*; and *thalamos*, chamber). Possessing only a single chamber. Applied to the shells of *Foraminifera* and *Mollusca*.

Monotremata (Gr. *monos*; *trema*, aperture). The order of Mammals comprising the Duck-mole and *Echidna*, in which the intestinal canal opens into a "cloaca" common to the ducts of the urinary and generative organs.

Multilocular (Lat. *multus*, many; *loculus*, a little purse). Divided into many chambers.

Multivalve. Applied to shells which are composed of many pieces.

Multungula (Lat. *multus*, many; *ungula*, hoof). The division of Perissodactyle Ungulates, in which each foot has more than a single hoof.

Myriapoda or Myriopoda (Gr. *murios*, ten thousand; *podes*, feet). A class of *Arthropoda* comprising the Centipedes and their allies, characterised by their numerous feet.

Nacreous (Fr. *nacre*, mother-of-pearl, originally oriental). Pearly; of the texture of mother-of-pearl.

Natatores (Lat. *nare*, to swim). The order of the Swimming Birds.

Natatory (Lat. *nare*, to swim). Formed for swimming.

Nautiloid. Resembling the shell of the *Nautilus* in shape.

Nervures (Lat. *nervus*, a sinew). The ribs which support the membranous wings of insects.

Neural (Gr. *neuron*, a nerve). Connected with the nervous system.

Neurapophysis (Gr. *neuron*, a nerve; *apophusis*, a projecting part). The "spinous process" of a vertebra, or the process formed at the point of junction of the neural arches.

Neuroptera (Gr. *neuron*; and *pteron*, a wing). An order of insects characterised by four membranous wings with numerous reticulated nervures (*e.g.*, Dragon-flies).

Nocturnal (Lat. *nox*, night). Applied to animals which are active by night.

Normal (Lat. *norma*, a rule). Conforming to the ordinary standard.

NOTOBRANCHIATA (Gr. *notos*, the back; and *bragchia*, gill). Carrying the gills upon the back; applied to a division of the *Annelida*.

NOTOCHORD (Gr. *notos*, back; *chorde*, string). A cellular rod which is developed in the embryo of Vertebrates immediately beneath the spinal cord, and which is usually replaced in the adult by the vertebral column. Often it is spoken of as the "chorda dorsalis."

NUDIBRANCHIATA (Lat. *nudus*, naked; and Gr. *bragchia*, gill). An order of the *Gasteropoda* in which the gills are naked.

NUMMULINA (Lat. *nummus*, a coin). A genus of coin-shaped Foraminifers of the Eocene period. Often spoken of as "Nummulites."

OCCIPITAL. Connected with the *occiput*, or the back part of the head.

OCEANIC. Applied to animals which inhabit the open ocean (=pelagic).

OCELLI (Lat. diminutive of *oculus*, eye). The simple eyes of many Echinoderms, Spiders, Crustaceans, Molluscs, &c.

OCTOPODA (Gr. *octo*, eight; *pous*, foot). The tribe of Cuttle-fishes with eight arms attached to the head.

ODONTOCETI (Gr. *odous*, tooth; *ketos*, whale). The "toothed" Whales, in contradistinction to the "whalebone" Whales.

ODONTOID (Gr. *odous; eidos*, form). The "odontoid process" is the centrum or body of the first cervical vertebra (*atlas*). It is detached from the atlas, and is usually anchylosed with the second cervical vertebra (*axis*), and it forms the pivot upon which the head rotates.

ODONTOPHORE (Gr. *odous*, tooth; *phero*, I carry). The so-called "tongue," or masticatory apparatus of *Gasteropoda*, *Pteropoda*, and *Cephalopoda*.

ŒSOPHAGUS. The gullet or tube leading from the mouth to the stomach.

OLIGOCHÆTA (Gr. *oligos*, few; *chaite*, hair). An order of *Annelida*, comprising the Earth-worms, in which there are few bristles.

OMNIVOROUS (Lat. *omnia*, everything; *voro*, I devour). Feeding indiscriminately upon all sorts of food.

OPERCULATA (Lat. *operculum*, a lid). A division of pulmonate *Gasteropoda*, in which the shell is closed by an operculum.

OPERCULUM. A horny or shelly plate developed in certain *Mollusca* upon the hinder part of the foot, and serving to close the aperture of the shell when the animal is retracted within it; also the lid of the shell of a *Balanus* or Acorn-shell; also the chain of flat bones which cover the gills in many fishes.

OPHIDIA (Gr. *ophis*, a serpent). The order of Reptiles comprising the Snakes.

OPHIDOBATRACHIA (Gr. *ophis; batrachos*, a frog). Sometimes applied to the order of Snake-like Amphibians comprising the *Cœciliæ*.

OPHIOMORPHA (Gr. *ophis; morphe*, shape). The order of *Amphibia* comprising the *Cœciliæ*.

OPHIUROIDEA (Gr. *ophis*, snake; *oura*, tail; *eidos*, form). An order of *Echinodermata*, comprising the Brittle-stars and Sand-stars.

OPISTHOBRANCHIATA (Gr. *opisthen*, behind; *bragchia*, gill). A division of *Gasteropoda* in which the gills are placed on the posterior part of the body.

OPISTHOCŒLOUS (Gr. *opisthen*, behind; *koilos*, hollow). Applied to vertebræ, the bodies of which are hollow or concave behind.

ORAL (Lat. *os*, mouth). Connected with the mouth.

Ornithodelphia (Gr. *ornis*, a bird; *delphus*, womb). The primary division of Mammals comprising the *Monotremata*.

Ornithoscelida (Gr. *ornis*, bird; *skelos*, leg). Applied by Huxley to the Deinosaurian Reptiles, together with the genus *Compsognathus*, on account of the bird-like character of their hind-limbs.

Orthoceratidæ (Gr. *orthos*, straight; *keras*, horn). A family of the *Nautilidæ*, in which the shell is straight, or nearly so.

Orthoptera (Gr. *orthos*, straight; *pteron*, wing). An order of Insects.

Ossicula (Lat. diminutive of *os*, bone). Literally small bones. Often used to designate any hard structures of small size, such as the calcareous plates in the integument of the Star-fishes.

Ostracoda (Gr. *ostrakon*, a shell). An order of small Crustaceans which are enclosed in bivalve shells.

Otoliths (Gr. *ous*, ear; and *lithos*, stone). The calcareous bodies connected with the sense of hearing, even in its most rudimentary form.

Ovarian Vesicles or Capsules. The generative buds of the *Sertularida*.

Pachydermata (Gr. *pachus*, thick; *derma*, skin). An old Mammalian order constituted by Cuvier for the reception of the Rhinoceros, Hippopotamus, Elephant, &c.

Palæontology (Gr. *palaios*, ancient; *onta*, beings; and *logos*, discourse). The science of fossil remains or of extinct organised beings.

Palæotheridæ (Gr. *palaios*, ancient; *ther*, beast). A group of Tertiary Ungulates.

Palæozoic (Gr. *palaios*, ancient; and *zoe*, life). Applied to the oldest of the great geological epochs.

Palliobranchiata (Lat. *pallium*; and Gr. *bragchia*, gill). An old name for the *Brachiopoda*, founded upon the belief that the system of tubes in the mantle constituted the gills.

Pallium (Lat. *pallium*, a cloak). The mantle of the *Mollusca*. *Pallial*: relating to the mantle. *Pallial line* or *impression*: the line left in the dead shell by the muscular margin of the mantle. *Pallial shell*: a shell which is secreted by, or contained within, the mantle, such as the "bone" of the Cuttle-fishes.

Palpi (Lat. *palpo*, I touch). Processes supposed to be organs of touch, developed from certain of the oral appendages in Insects, Spiders, and Crustacea, and from the sides of the mouth in the Acephalous Molluscs.

Papilla (Lat. for nipple). A minute soft prominence.

Parapodia (Gr. *para*, beside; *podes*, feet). The unarticulated lateral locomotive processes or "foot-tubercles" of many of the *Annelida*.

Parietal (Lat. *paries*, a wall). Connected with the walls of a cavity or of the body.

Patagium (Lat. the border of a dress). Applied to the expansion of the integument by which Bats, Flying Squirrels, and other animals support themselves in the air.

Patella. The knee-cap or knee-pan. A sesamoid bone developed in the tendon of insertion of the great extensor muscles of the thigh.

Pectinate (Lat. *pecten*, a comb). Comb-like; applied to the gills of certain *Gasteropods*, hence called *Pectinibranchiata*.

Pectoral (Lat. *pectus*, chest). Connected with, or placed upon, the chest.

PEDAL (Lat. *pes*, the foot). Connected with the foot of *Mollusca*.

PEDICELLARIÆ (Lat. *pedicellus*, a louse). Certain singular appendages found in many *Echinoderms*, attached to the surface of the body, and resembling a little beak or forceps supported on a stalk.

PEDICLE (Lat. dim. of *pes*, the foot). A little stem.

PEDIPALPI (Lat. *pes*, foot; and *palpo*, I feel). An order of *Arachnida* comprising the Scorpions, &c.

PEDUNCLE (Lat. *pedunculus*, a stem or stalk). In a restricted sense applied to the muscular process by which certain *Brachiopods* are attached, and to the stem which bears the body (capitulum) in Barnacles.

PEDUNCULATE. Possessing a peduncle.

PELAGIC (Gr. *pelagos*, sea). Inhabiting the open ocean.

PELVIS (Lat. for basin). Applied, from analogy, to the basal portion of the cup (*calyx*) of *Crinoids*. The bony arch with which the hind-limbs are connected in Vertebrates.

PERENNIBRANCHIATA (Lat. *perennis*, perpetual; Gr. *bragchia*, gill). Applied to those *Amphibia* in which the gills are permanently retained throughout life.

PERGAMENTACEOUS (Lat. *pergamena*, parchment). Of the texture of parchment.

PERIOSTRACUM (Gr. *peri*, around; and *ostrakon*, shell). The layer of epidermis which covers the shell in most of the *Mollusca*.

PERISOME (Gr. *peri*; and *soma*, body). The coriaceous or calcareous integument of the *Echinodermata*.

PERISSODACTYLA (Gr. *perissos*, uneven; *daktulos*, finger). Applied to those Hoofed Quadrupeds (*Ungulata*) in which the feet have an uneven number of toes.

PETALOID. Shaped like the petal of a flower.

PHALANGES (Gr. *phalanx*, a row). The small bones composing the digits of the higher *Vertebrata*. Normally each digit has three phalanges.

PHANEROGAMS (Gr. *phaneros*, visible; *gamos*, marriage). Plants which have the organs of reproduction conspicuous, and which bear true flowers.

PHARYNGOBRANCHII (Gr. *pharugx*, pharynx; *bragchia*, gill). The order of Fishes comprising only the Lancelet.

PHARYNX. The dilated commencement of the gullet.

PHRAGMACONE (Gr. *phragma*, a partition; and *konos*, a cone). The chambered portion of the internal shell of a *Belemnite*.

PHYLACTOLÆMATA (Gr. *phulasso*, I guard; and *laimos*, throat). The division of *Polyzoa* in which the mouth is provided with the arched valvular process known as the "epistome."

PHYLLOPODA (Gr. *phullon*, leaf; and *pous*, foot). An order of *Crustacea*.

PHYSOPHORIDÆ (Gr. *phusa*, air-bladder; and *phero*, I carry). An order of Oceanic *Hydrozoa*.

PHYTOID (Gr. *phuton*, a plant; and *eidos*, form). Plant-like.

PHYTOPHAGOUS (Gr. *phuton*, a plant; and *phago*, I eat). Plant-eating, or herbivorous.

PINNATE (Lat. *pinna*, a feather). Feather-shaped; or possessing lateral processes.

PINNIGRADA (Lat. *pinna*, a feather; *gradior*, I walk). The group of *Carnivora*, comprising the Seals and Walruses, adapted for an aquatic life. Often called *Pinnipedia*.

Pinnulæ (Lat. dim. of *pinna*). The lateral processes of the arms of *Crinoids*.

Pisces (Lat. *piscis*, a fish). The class of Vertebrates comprising the Fishes.

Placenta (Lat. a cake). The "after-birth," or the organ by which a vascular connection is established in the higher *Mammalia* between the mother and the fœtus.

Placental. Possessing a placenta; or connected with the placenta.

Placoid (Gr. *plax*, a plate; *eidos*, form). Applied to the irregular bony plates, grains, or spines which are found in the skin of various fishes (*Elasmobranchii*).

Plagiostomi (Gr. *plagios*, transverse; *stoma*, mouth). The Sharks and Rays, in which the mouth is transverse, and is placed on the under surface of the head.

Plantigrade (Lat. *planta*, the sole of the foot; *gradior*, I walk). Applying the sole of the foot to the ground in walking.

Plastron. The lower or ventral portion of the bony case of the Chelonians.

Platyrhina (Gr. *platus*, broad; *rhines*, nostrils). A group of the *Quadrumana*.

Pleistocene (Gr. *pleistos*, most; *kainos*, new). Often used as synonymous with "Post-Pliocene."

Pleurodont (Gr. *pleuron*, rib, side; *odous*, tooth). Having the teeth anchylosed with the inner side of the jaws.

Pleuron (Gr. *pleuron*, a rib). The lateral extensions of the shell of *Crustacea*.

Pneumatic (Gr. *pneuma*, air). Filled with air.

Podophthalmata (Gr. *pous*, foot; and *ophthalmos*, eye). The division of Crustacea in which the eyes are borne at the end of long footstalks.

Pollex (Lat. the thumb). The innermost of the five normal digits of the anterior limb of the higher Vertebrates. In man, the thumb.

Polycystina (Gr. *polus*, many; and *kustis*, a cyst). An order of *Protozoa*, with foraminated siliceous shells.

Polypary. The hard chitinous covering secreted by many of the *Hydrozoa*.

Polype (Gr. *polus*, many; *pous*, foot). Restricted to the single individual of a simple *Actinozoön*, such as a Sea-anemone, or to the separate zoöids of a compound *Actinozoön*. Often applied indiscriminately to any of the *Cœlenterata*, or even to the *Polyzoa*.

Polypide. The separate zoöid of a *Polyzoön*.

Polypidom. The dermal system of a colony of a *Hydrozoön*, or *Polyzoön*.

Polypite. The separate zoöid of a *Hydrozoön*.

Polythalamous (Gr. *polus*; and *thalamos*, chamber). Having many chambers; applied to the shells of *Foraminifera* and *Cephalopoda*.

Polyzoa (Gr. *polus*; and *zoön*, animal). A division of the *Molluscoida* comprising compound animals such as the Sea-mat — sometimes called *Bryozoa*.

Polyzoarium. The dermal system of the colony of a *Polyzoön* (= Polypidom).

Porcellanous. Of the texture of porcelain.

Porifera (Lat. *porus*, a pore; and *fero*, I carry). Sometimes used to designate the *Foraminifera*, or the *Sponges*.

Post-anal. Situated behind the anus.

Post-œsophageal. Situated behind the gullet.

Post-oral. Situated behind the mouth.

Præmaxillæ—*see* Intermaxillæ.

Præmolars (Lat. *præ*, before; *molares*, the grinders). The molar teeth of

Mammals which succeed the molars of the milk-set of teeth. In man, the bicuspid teeth.

Præ-œsophageal. Situated in front of the gullet.

Præ-sternum. The anterior portion of the breast-bone, corresponding with the *manubrium sterni* of human anatomy, and extending as far as the point of articulation of the second rib.

Proboscidea (Lat. *proboscis*, the snout). The order of Mammals comprising the Elephants.

Procœlous (Gr. *pro*, before; *koilos*, hollow). Applied to vertebræ, the bodies of which are hollow or concave in front.

Propodium (Gr. *pro*, before; *pous*, foot). The anterior part of the foot in Molluscs.

Prosobranchiata (Gr. *proson*, in advance of; *bragchia*, a gill). A division of Gasteropodous Molluscs in which the gills are situated in advance of the heart.

Prosoma (Gr. *pro*, before; *soma*, body). The anterior part of the body.

Prothorax (Gr. *pro*; and *thorax*, chest). The anterior ring of the thorax of insects.

Protophyta (Gr. *protos*; and *phuton*, plant). The lowest division of plants.

Protoplasm (Gr. *protos*; and *plasso*, I mould). The elementary basis of organised tissues. Sometimes used synonymously for the "sarcode" of the *Protozoa*.

Protopodite (Gr. *protos*, first; and *pous*, foot). The basal segment of the typical limb of a *Crustacean*.

Protozoa (Gr. *protos*; and *zoön*, animal). The lowest division of the animal kingdom.

Proximal (Lat. *proximus*, next). Applied to the slowly-growing, comparatively-fixed extremity of a limb or of an organism; or to the end nearest to the trunk.

Pseudopodia (Gr. *pseudos*, falsity; and *pous*, foot). The extensions of the body-substance which are put forth by the *Rhizopoda* at will, and which serve for locomotion and prehension.

Pteropoda (Gr. *pteron*, wing; and *pous*, foot). A class of the *Mollusca* which swim by means of fins attached near the head.

Pterosauria (Gr. *pteron*, wing; *saura*, lizard). An extinct order of Reptiles.

Pubis (Lat. *pubes*, hair). The share-bone; one of the bones which enter into the composition of the pelvic arch of Vertebrates.

Pulmogasteropoda (=Pulmonifera).

Pulmonaria. A division of *Arachnida* which breathe by means of pulmonary sacs.

Pulmonifera (Lat. *pulmo*, a lung; and *fero*, I carry). The division of *Mollusca* which breathe by means of a pulmonary chamber.

Pulmonate. Possessing lungs.

Pyriform (Lat. *pyrus*, a pear; and *forma*, form). Pear-shaped.

Quadrumana (Lat. *quatuor*, four; *manus*, hand). The order of Mammals comprising the Apes, Monkeys, Baboons, Lemurs, &c.

Radiata (Lat. *radius*, a ray). Formerly applied to a large number of animals

which are now placed in separate sub-kingdoms (*e.g.*, the *Cœlenterata*, the *Echinodermata*, the *Infusoria*, &c.)

Radiolaria (Lat. *radius*, a ray). A division of *Protozoa*.

Radius (Lat. a spoke or ray). The innermost of the two bones of the fore-arm of the higher Vertebrates. It carries the thumb, when present, and corresponds with the tibia of the hind-limb.

Ramus (Lat. a branch). Applied to each half or branch of the lower jaw, or mandible, of Vertebrates.

Raptores (Lat. *rapto*, I plunder). The order of the Birds of Prey.

Rasores (Lat. *rado*, I scratch). The order of the Scratching Birds (Fowls, Pigeons, &c.)

Ratitæ (Lat. *rates*, a raft). . Applied by Huxley to the Cursorial Birds, which do not fly, and have therefore a raft-like sternum without any median keel.

Rectum (Lat. *rectus*, straight). The terminal portion of the intestinal canal, opening at the surface of the body at the anus.

Reptilia (Lat. *repto*, I crawl). The class of the *Vertebrata*, comprising the Tortoises, Snakes, Lizards, Crocodiles, &c.

Reversed. Applied to spiral Univalves, in which the direction of the spiral is the reverse of the normal—*i.e.*, *sinistral*.

Rhizophaga (Gr. *rhiza*, root; *phago*, I eat). A group of the Marsupials.

Rhizopoda (Gr. *rhiza*, a root; and *pous*, foot). The division of *Protozoa*, comprising all those which are capable of emitting pseudopodia.

Rhyncholites (Gr. *rhunchos*, beak; and *lithos*, stone). Beak-shaped fossils consisting of the mandibles of *Cephalopoda*.

Rodentia (Lat. *rodo*, I gnaw). An order of the Mammals ; often called *Glires* (Lat. *glis*, a dormouse).

Rugosa (Lat. *rugosus*, wrinkled). An order of Corals.

Ruminantia (Lat. *ruminor*, I chew the cud). The group of Hoofed Quadrupeds (*Ungulata*) which "ruminate" or chew the cud.

Sacrum. The vertebræ (usually anchylosed) which unite with the haunch-bones (*ilia*) to form the pelvis.

Sand-canal (= Stone-canal). The tube by which water is conveyed from the exterior to the ambulacral system of the *Echinodermata*.

Sarcode (Gr. *sarx*, flesh; *eidos*, form). The jelly-like substance of which the bodies of the *Protozoa* are composed. It is an albuminous body containing oil-granules, and is sometimes called "animal protoplasm."

Sarcoids (Gr. *sarx;* and *eidos*, form). The separate amœbiform particles which in the aggregate make up the "flesh" of a Sponge.

Sauria (Gr. *saura*, a lizard). Any lizard-like Reptile is often spoken of as a "Saurian;" but the term is sometimes restricted to the Crocodiles alone, or to the Crocodiles and Lacertilians.

Saurobatrachia (Gr. *saura ; batrachos*, frog). Sometimes applied to the order of the tailed Amphibians (*Urodela*).

Sauropsida (Gr. *saura ;* and *opsis*, appearance). The name given by Huxley to the two classes of the Birds and Reptiles collectively.

Sauropterygia (Gr. *saura; pterux*, wing). An extinct order of Reptiles, called by Huxley *Plesiosauria*, from the typical genus *Plesiosaurus*.

Saurure (Gr. *saura ; oura*, tail). The extinct order of Birds comprising only the *Archæopteryx*.

Scansores (Lat. *scando*, I climb). The order of the Climbing Birds (Parrots, Woodpeckers, &c.)

Scapula (Lat. for shoulder-blade). The shoulder-blade of the pectoral arch of Vertebrates; in a restricted sense, the row of plates in the cup of *Crinoids*, which give origin to the arms, and are usually called the "axillary radials."

Sclerenchyma (Gr. *skleros*, hard; and *enchuma*, tissue). The calcareous tissue of which a coral is composed.

Sclerobasic (Gr. *skleros*, hard; *basis*, pedestal). The coral which is produced by the outer surface of the integument in certain *Actinozoa* (*e.g.*, Red Coral), and forms a solid axis which is invested by the soft parts of the animal. It is called "foot-secretion" by Dana.

Scleroderмic (Gr. *skleros;* and *derma*, skin). Applied to the corallum which is deposited within the tissues of certain *Actinozoa*, and is called "tissue-secretion" by Dana.

Sclerotic (Gr. *skleros*, hard). The outer dense fibrous coat of the eye.

Scolecida (Gr. *skolēx*, worm). A division of the *Annuloida*.

Scuta (Lat. *scutum*, a shield). Applied to any shield-like plates; especially to those which are developed in the integument of many Reptiles.

Selachia or Selachii (Gr. *selachos*, a cartilaginous fish, probably a shark). The sub-order of *Elasmobranchii*, comprising the Sharks and Dog-fishes.

Sepiostaire. The internal shell of the Sepia, commonly known as the "cuttle-bone."

Septa. Partitions.

Serpentiform. Resembling a serpent in shape.

Sertularida (Lat. *sertum*, a wreath). An order of *Hydrozoa*.

Sessile (Lat. *sedo*, I sit). Not supported upon a stalk or peduncle; attached by a base.

Setæ (Lat. bristles). Bristles or long stiff hairs.

Setiferous. Supporting bristles.

Setigerous (= Setiferous).

Setose. Bristly.

Sigillarioids (Lat. *sigilla*, little images). A group of extinct plants of which *Sigillaria* is the type, so called from the seal-like markings on the bark.

Siliceous (Lat. *silex*, flint). Composed of flint.

Sinistral (Lat. *sinistra*, the left hand). Left-handed; applied to the direction of the spiral in certain shells, which are said to be "reversed."

Siphon (Gr. *siphon*, a tube). Applied to the respiratory tubes in the *Mollusca;* also to other tubes of different functions.

Siphonophora (Gr. *siphon;* and *phero*, I carry). A division of the *Hydrozoa* comprising the Oceanic forms (*Calycophoridæ* and *Physophoridæ*).

Siphonostomata (Gr. *siphon;* and *stoma*, mouth). The division of *Gasteropodous Molluscs*, in which the aperture of the shell is not "entire," but possesses a notch or tube for the emission of the respiratory siphon.

Siphuncle (Lat. *siphunculus*, a little tube). The tube which connects together the various chambers of the shell of certain *Cephalopoda* (*e.g.*, the Pearly Nautilus).

Sipunculoidea (Lat. *siphunculus*, a little siphon). A class of *Anarthropoda* (*Annulosa*).

Sirenia (Gr. *seiren*, a mermaid). The order of *Mammalia* comprising the Dugongs and Manatees.

Solidungula (Lat. *solidus*, solid; *ungula*, a hoof). The group of Hoofed Quadrupeds comprising the Horse, Ass, and Zebra, in which each foot has only a single solid hoof. Often called *Solipedia*.

Somatic (Gr. *soma*, body). Connected with the body.

Somite (Gr. *soma*). A single segment in the body of an Articulate animal.

Spermatozoa (Gr. *sperma*, seed; and *zoön*, animal). The microscopic filaments which form the essential generative element of the male.

Spicula (Lat. *spiculum*, a point). Pointed needle-shaped bodies.

Spiracles (Lat. *spiro*, I breathe). The breathing-pores, or apertures of the breathing-tubes (tracheæ) of Insects. Also the single nostril of the Hag-fishes, the "blow-hole" of Cetaceans, &c.

Splanchnoskeleton (Gr. *splagchna*, viscera; *skeletos*, dry). The hard structures occasionally developed in connection with the internal organs or viscera.

Sponge-particles—*see* Sarcoids.

Spongida (Gr. *spoggos*, a sponge). The division of *Protozoa* commonly known as Sponges.

Squamata (Lat. *squama*, a scale). The division of Reptiles comprising the *Ophidia* and *Lacertilia*, in which the integument develops horny scales, but there are no dermal ossifications.

Stellerida (Lat. *stella*, star). Sometimes employed to designate the order of the Star-fishes.

Stelliform. Star-shaped.

Sternum (Gr. *sternon*). The breast-bone.

Stolon (Gr. *stolos*, a sending forth). Offshoots. The connecting processes of sarcode, in *Foraminifera*; the connecting tube in the social *Ascidians*; the processes sent out by the cœnosarc of certain *Actinozoa*.

Stomapoda (Gr. *stoma*, mouth; *pous*, foot). An order of *Crustacea*.

Stomatode (Gr. *stoma*). Possessing a mouth. The *Infusoria* are thus often called the Stomatode *Protozoa*.

Strepsiptera (Gr. *strepho*, I twist; and *pteron*, wing). An order of Insects in which the anterior wings are represented by twisted rudiments.

Strepsirhina (Gr. *strepho*, I twist; *rhines*, nostrils). A group of the Quadrumana, often spoken of as *Prosimiæ*.

Styliform (Lat. *stylus*, a pointed instrument; *forma*, form). Pointed in shape.

Sub-calcareous. Somewhat calcareous.

Sub-central. Nearly central, but not quite.

Sub-pedunculate. Supported upon a very short stem.

Sub-sessile. Nearly sessile, or without a stalk.

Suture (Lat. *suo*, I sew). The line of junction of two parts which are immovably connected together. Applied to the line where the whorls of a univalve shell join one another; also to the lines made upon the exterior of the shell of a chambered *Cephalopod* by the margins of the septa.

Swimmerets. The limbs of *Crustacea*, which are adapted for swimming.

Symphysis (Gr. *sumphusis*, a growing together). Union of two bones in which there is no motion or but a very limited amount.

SYNAPTICULÆ (Gr. *sunapto*, I fasten together). Transverse props sometimes found in Corals, extending across the loculi like the bars of a grate.

TABULÆ (Lat. *tabula*, a tablet). Horizontal plates or floors found in some Corals, extending across the cavity of the "theca" from side to side.

TACTILE (Lat. *tango*, I touch). Connected with the sense of touch.

TARSO-METATARSUS. The single bone in the leg of Birds produced by the union and anchylosis of the lower or distal portion of the tarsus with the whole of the metatarsus.

TARSUS (Gr. *tarsos*, the flat of the foot). The small bones which form the ankle (or "instep" of man), and which correspond with the wrist (*carpus*) of the anterior limb.

TECTIBRANCHIATA (Lat. *tectus*, covered; and Gr. *bragchia*, gills). A division of *Opisthobranchiate Gasteropoda* in which the gills are protected by the mantle.

TEGUMENTARY (Lat. *tegumentum*, a covering). Connected with the integument or skin.

TELEOSTEI (Gr. *teleios*, perfect; *osteon*, bone). The order of the "Bony Fishes."

TELSON (Gr. *telson*, a limit). The last joint in the abdomen of *Crustacea;* variously regarded as a segment without appendages, or as an azygous appendage.

TERGUM (Lat. for back). The dorsal arc of the somite of an Arthropod.

TERRICOLA (Lat. *terra*, earth; and *colo*, I inhabit). Employed occasionally to designate the Earth-worms (*Lumbricidæ*).

TEST (Lat. *testa*, shell). The shell of *Mollusca*, which are for this reason sometimes called "*Testacea;*" also, the calcareous case of *Echinoderms;* also, the thick, leathery, outer tunic in the *Tunicata.*

TESTACEOUS. Provided with a shell or hard covering.

TETRABRANCHIATA (Gr. *tetra*, four; *bragchia*, gill). The order of *Cephalopoda* characterised by the possession of four gills.

THALASSICOLLIDA (Gr. *thalassa*, sea; *kolla*, glue). A division of *Protozoa.*

THECA (Gr. *theke*, a sheath). A sheath or receptacle.

THECOSOMATA (Gr. *theke;* and *soma*, body). A division of *Pteropodous Molluscs*, in which the body is protected by an external shell.

THERIODONTIA (Gr. *therion*, a beast; *odous*, tooth). A group of Reptiles so named by Owen in allusion to the Mammalian character of their teeth.

THERIOMORPHA (Gr. *ther*, beast; *morphe*, shape). Applied by Owen to the order of the Tail-less Amphibians (*Anoura*).

THORAX (Gr. a breast-plate). The chest.

TIBIA (Lat. a flute). The shin-bone, being the innermost of the two bones of the leg, and corresponding with the *radius* in the anterior extremity.

TOTIPALMATÆ (Lat. *totus*, whole; *palma*, the palm of the hand). A group of Wading Birds in which the hallux is united to the other toes by membrane, so that the feet are completely webbed.

TRACHEA (Gr. *tracheia*, the rough windpipe). The tube which conveys air to the lungs in the air-breathing Vertebrates.

TRACHEÆ. The breathing-tubes of Insects and other Articulate animals.

TRACHEARIA. The division of *Arachnida* which breathe by means of tracheæ.

Trilobita (Gr. *treis*, three; *lobos*, a lobe). An extinct order of *Crustaceans*.

Trochanter (Gr. *trecho*, I turn). A process of the upper part of the thigh-bone (*femur*) to which are attached the muscles which rotate the limb. There may be two, or even three, trochanters present.

Trochoid (Gr. *trochos*, a wheel; and *eidos*, form). Conical with a flat base; applied to the shells of *Foraminifera* and *Univalve Molluscs*.

Trophi (Gr. *trophos*, a nourisher). The parts of the mouth in insects which are concerned in the acquisition and preparation of food. Often called "instrumenta cibaria."

Trophosome (Gr. *trepho*, I nourish; and *soma*, body). Applied collectively to the assemblage of the nutritive zoöids of any *Hydrozoön*.

Truncated (Lat. *trunco*, I shorten). Abruptly cut off; applied to univalve shells, the apex of which breaks off, so that the shell becomes "decollated."

Tubicola (Lat. *tuba*, a tube; and *colo*, I inhabit). The order of *Annelida* which construct a tubular case in which they protect themselves.

Tubicolous. Inhabiting a tube.

Tunicata (Lat. *tunica*, a cloak). A class of *Molluscoida* which are enveloped in a tough leathery case or "test."

Turbinated (Lat. *turbo*, a top). Top-shaped; conical with a round base.

Ulna (Gr. *olene*, the elbow). The outermost of the two bones of the fore-arm, corresponding with the *fibula* of the hind-limb.

Umbellate (Lat. *umbella*, a parasol). Forming an umbel—*i.e.*, a number of nearly equal *radii* all proceeding from one point.

Umbilicus (Lat. for navel). The aperture seen at the base of the axis of certain univalve shells, which are then said to be "perforated" or "umbilicated."

Umbo (Lat. the boss of a shield). The beak of a bivalve shell.

Umbrella. The contractile disc of one of the *Lucernarida*.

Uncinate (Lat. *uncinus*, a hook). Provided with hooks or bent spines.

Unguiculate (Lat. *unguis*, nail). Furnished with claws.

Ungulata (Lat. *ungula*, hoof). The order of *Mammals* comprising the Hoofed Quadrupeds.

Ungulate. Furnished with expanded nails constituting hoofs.

Unilocular (Lat. *unus*, one; and *loculus*, a little purse). Possessing a single cavity or chamber. Applied to the shells of *Foraminifera* and *Mollusca*.

Univalve (Lat. *unus*, one; *valvæ*, folding-doors). A shell composed of a single piece or valve.

Urodela (Gr. *oura*, tail; *delos*, visible). The order of the Tailed Amphibians (Newts, &c.)

Varices (Lat. *varix*, a dilated vein). The ridges or spinose lines which mark the former position of the mouth in certain univalve shells.

Vascular (Lat. *vas*, a vessel). Connected with the circulatory system.

Ventral (Lat. *venter*, the stomach). Relating to the inferior surface of the body.

Vermes (Lat. *vermis*, a worm). Sometimes employed at the present day in the same, or very nearly the same, sense as *Annuloida*, or as *Annuloida* plus the *Anarthropoda*.

VERMIFORM (Lat. *vermis*, worm; and *forma*, form). Worm-like.

VERTEBRA (Lat. *verto*, I turn). One of the bony segments of the vertebral column or backbone.

VERTEBRATA (Lat. *vertebra*, a bone of the back, from *vertere*, to turn). The division of the Animal Kingdom roughly characterised by the possession of a backbone.

VESICLE (Lat. *vesica*, a bladder). A little sac or cyst.

VIBRACULA (Lat. *vibro*, I shake). Long filamentous appendages found in many *Polyzoa*.

VIPERINA (Lat. *vipera*, a viper). A group of the Snakes.

VIVIPAROUS (Lat. *vivus*, alive; and *pario*, I bring forth). Bringing forth young alive.

WHORL. The spiral turn of a univalve shell.

XIPHISTERNUM (Gr. *xiphos*, sword; *sternon*, breast-bone). The inferior or posterior segment of the sternum, corresponding with the "xiphoid cartilage" of human anatomy.

XIPHOSURA (Gr. *xiphos*, a sword; and *oura*, tail). An order of *Crustacea*, comprising the *Limuli* or King-crabs, characterised by their long sword-like-tails.

ZEUGLODONTIDÆ (Gr. *zeugle*, a yoke; *odous*, a tooth). An extinct family of Cetaceans, in which the molar teeth are two-fanged and look as if composed of two parts united by a neck.

ZOÖID (Gr. *zoön*, animal; and *eidos*, like). The more or less completely independent organisms produced by gemmation or fission, whether these remain attached to one another or are detached and set free.

ZOOPHYTE (Gr. *zoön*, animal; *phuton*, plant). Loosely applied to many plant-like animals, such as Sponges, Corals, Sea-anemones, Sea-mats, &c.

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